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COOPERATION IN DEVELOPMENT AND PRODUCTION OF NATO WEAPONS: An Evaluation of Tactical Missile Programs

Herschel Kanter
John Fry

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This report examines the prospects of NATO cooperation in the development and production of tactical missiles. It presents the quantitative background of arms production and trade among the four major arms producers in NATO: France, FRG, UK, and US. The views of senior European government officials concerning arms cooperation are presented using their public statements on the subject made on both sides of the Atlantic. The study then turns to NATO tactical missiles. After tracing the history of missile development since

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World War II, the study then measures the interest and capability of the four countries in the various types of tactical missiles, based on production, exports, development spending, and force levels--using both recent figures and totals for the last 30 years. Estimates of development cost savings are made for the past based on a program of complete four power cooperation. Estimates of development cost savings are made for the future by comparing a program of complete cooperation with an expected or most likely program. Conclusions are presented concerning the difficulty of attaining further cooperation beyond that already achieved.

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PREFACE

The research for this paper was completed by October 1979 and then updated through March 1980. We have followed the subject rather closely since then but have cited only a small number of more recent articles. Based on our continuing research, we believe nothing has occurred since that would change our findings.

The sources used were unclassified, many of them European in origin. Most useful was Bill Gunston's *The Illustrated Encyclopedia of the World's Rockets and Missiles*. Other particularly useful sources for missile information included *Jane's* and reference sources published by Data Search Associates and General Dynamics, Pomona Division.

Some 20 European journals and trade publications in English and French were consulted as well as a number of European government documents. The journals were published in France, Germany, Switzerland, and the United Kingdom while government documents were available from France, Germany, and the United Kingdom. Although these European sources tended to duplicate the US trade publications, journals and government documents, they offered some supplemental data and--what is more important--a substantially different perspective on the problems of cooperation in the development and production of NATO weapons.

An attempt was made to preserve internal consistency within the study. A larger problem than consistency was the fact many of our categorizations and classifications of weapons were--by necessity--arbitrary. A reader might well disagree, for good reason, with one or another of our choices. We attempted,

therefore, to offer enough information for the reader to see whether a different approach or classification might yield a different answer. We believe, however, that most of our conclusions are robust with respect to these arbitrary choices.

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Among those who contributed to the study, Brenda Van Lunen provided research assistance; Eileen Doherty edited the manuscript; Debbie Vogel typed the earlier drafts; and Lovie Whyte typed the later drafts, arranged the format of the 40 or so tables, and handled the layout of the report. The study was reviewed by Norman Asher (IDA), Seymour Deitchman (IDA), Robert Gessert (General Research Corporation), and Harry Williams (IDA). Any errors are the responsibility of the authors.

EXECUTIVE SUMMARY

A. FORMS OF NATO ARMS COOPERATION

For the 30 years that NATO has existed, various attempts have been made to develop and produce identical (standardized) weapons for the military forces of the Alliance. The contention of advocates is that standardized weapons would save funds by eliminating duplicate development and by economies of scale in production as well as through common logistics support. Further, it is argued, the problem of operating together in wartime would be made simpler, thus increasing the effectiveness of the forces.

Militating against the use of common equipment have been a number of economic, technological, military, and political factors (Table S-1)--other than cost and military effectiveness--that have led the sovereign nations of NATO to equip their forces with a variety of weapons. In particular, the four major NATO arms producers--France, FRG, UK, and the US--have pursued parallel and often competitive programs, resulting in duplication of weapons systems many of which serve similar purposes and have in some cases almost identical characteristics.

The US has tended to emphasize cost and military effectiveness as the criteria by which to judge our armaments policy, although defense and foreign policy makers and reviewers in the Executive and Legislative Branches do not dismiss the other factors that influence weapons choices. The Europeans, on the other hand, tend to place greater emphasis on other factors beyond cost and military effectiveness.

There are a number of ways to pursue standardized weapons, either by adoption of existing systems or by cooperation

Table S-1. FACTORS AFFECTING WEAPONS DEVELOPMENT AND PRODUCTION CHOICES

ECONOMIC
• Employment
• Balance of Payments (US/Europe)
• Third Country Sales
TECHNOLOGICAL
• Security-Compromise (National and Industrial)
• Competitiveness in International Markets
• Prestige
MILITARY
• Ability to Stay Ahead of USSR
• Diversity of Weapons and Tactics
• Logistics/Inventory Commonality
• Common Training
• Non-European Contingencies
POLITICAL
• Sovereignty
• Flexibility Outside NATO
• Third Country Sales

in the research and development process. For already developed systems we have direct procurement, licensing, and cooperative production (coproduction). But the various approaches are not pure; rather, there can be licenses for "dual production" of the whole weapons system on both sides of the Atlantic as well as various degrees of cooperation in production from direct procurement of a whole system to coproduction led by the developing prime contractor.

By way of example, in the fighter aircraft area, the US has sold the F-4 to the Europeans, licensed the F-104 to three different consortia, and is now coproducing the F-16 with European subcontractors in Europe. In the case of the F-16, the subcontractors deal directly with General Dynamics. The British sold us the Harrier (to which we devoted development money) and

they are now considering buying our license-developed improvement, the AV-8B.

In the tactical missile area, two Raytheon-developed air defense systems--Hawk and Sea Sparrow--have been built by European consortia licensed by Raytheon. The US-developed Sparrow medium range air-to-air missile has been licensed separately by a British and an Italian firm. Each has developed and produced its own variants. Finally, the US developed the AIM-9L short range air-to-air missile and licensed it (except for several critical components) to be produced by a FRG-led European consortium. These critical components are sold rather than licensed for production.

Although licensing has been primarily for production of US-developed systems in Europe, it has gone in both directions across the Atlantic. The French and Germans developed the Roland short range land-based air defense system and sold the US a license to produce that weapon. The JP-233 airfield attack weapon is being developed in the UK with major support from the US; it is for use by both the US and UK and most likely for other NATO countries. Whether it will be produced in the US as well as the UK is unclear.

For future systems, the US has proposed the "family of weapons" approach, designed to eliminate competitive development work in two or more countries rather than postponing the cooperation until the production stage. Indeed, this proposal--in its present form--eliminates the cooperation in production, except for transfer of technical data. It is designed instead to save development funds and to provide for standardized weapons in the field, while allowing for dual (i.e., duplicate) production. The family of weapons concept calls for an agreement among the US, France, FRG, and the UK. The remaining members of the Alliance would be junior partners.

The family of weapons approach would begin in the initial planning phase where weapons would be aggregated by weapon type with responsibility equally divided for development of similar type weapons. For example, air-to-air missiles would be grouped together and the US and Canada, through a single prime contractor, would take responsibility for one weapon while the Europeans, through a consortium, would take responsibility for another. Competing work in advanced stages of development would be terminated. Production would be performed by the original developer on one side of the Atlantic and licensed for production on the other side of the Atlantic. Non-NATO sales would be limited by the consent of the country that developed the system. This approach is being negotiated, thus far, on air-to-air and anti-tank missiles with suggestions by the US that air-to-ground and anti-surface ship missiles, mines and torpedoes be added or at least considered.

Air defense weapons--in particular land-based surface-to-air missiles--have been explicitly excluded by the US from consideration under the family of weapons approach. Indeed, other major weapons have also been excluded--aircraft explicitly and tanks and ships by implication. Thus, the concept is not meant to apply (at least in the next few years) to the weapons with the greatest potential for savings in development and production. This is not surprising since these are also the weapons which would involve the most conflict on the economic, technological, military, and political issues cited in Table S-1.

Added to the problem of the many criteria applied by the four countries to the weapons process are procedural problems which place constraints on how the US and the Europeans plan, budget for and acquire weapons (see Table S-2 for US constraints). These systems, procedures, etc., have been built up over a period of years through law and custom. Thus, the first consideration is whether the US, itself, can accommodate the family of weapons approach or any cooperative system that involves major external constraints.

Table S-2. INSTITUTIONAL CONSTRAINTS IN THE US

PLANNING, PROGRAMMING, AND BUDGETING PROCESS FOR DEVELOPMENT, REVIEW, AND APPROVAL OF DOD SPENDING
Strategy
Doctrine
Acquisition
Programming
Annual Budget Review
Congressional Review
LAWS, REGULATIONS, POLICIES AFFECTING GOVERNMENT ACTION
Technology Transfer
National Security
Source Selection
Antitrust
Accounting and Auditing
Design to Cost
Value Engineering
Producibility
Operational Test and Evaluation
Arms Transfers

B. AN AGGREGATE VIEW OF NATO ARMS DEVELOPMENT, PRODUCTION, AND TRADE

Before considering the possibilities of US-European cooperation, it is important to realize the differences in scale between the US and the Europeans. The US defense equipment expenditures for armed forces and industrial output are both about twice that of the combined French-FRG-UK industrial output. In 1978 the US produced, for its own forces and for export, $30.0 billion in arms, while the major European producers produced $13.6 billion (Table S-3). Similarly, R&D expenditures were $10.8 billion compared to $4.2 billion for the Europeans. To equip its own forces the US was buying $20.6 billion in arms, while the three European countries were buying $9.5 billion in arms for their forces (Table S-4). The remainder of the production went for exports and even here the US was dominant by a ratio of 2:1.

Table S-3. ARMS ACTIVITY FOR WESTERN INDUSTRIAL COUNTRIES, 1978

(Billions of Dollars)

Category	Four Powers						Other Western Industrial Allies	Total Western Developed
		Major European						
	US	France	FRG	UK	Total	Total		
Production	30.0	5.4	3.1	5.1	13.6	43.6	5.8	49.4
R&D	10.8	1.6	0.9	1.7	4.2	15.0	0.2	15.2
TOTAL	40.8	7.0	4.0	6.8	17.8	58.6	6.0	64.6

Source: Table S-4.

Table S-4. EQUIPMENT EXPENDITURES, PROCUREMENT BY SOURCE OF PRODUCTION AND DELIVERIES BY CUSTOMER FOR WESTERN INDUSTRIAL COUNTRIES, 1978

(Billions of Dollars)

Category	Four Powers						Other Western Industrial Allies[a]	Total Western Developed
		Major European						
	US	France	FRG	UK	Total	Total		
Equipment Expenditures								
Total Procurement	20.6	2.7	3.0	3.8	9.5	30.1	6.6	36.7
R&D	10.8	1.6	0.9	1.7	4.2	15.0	0.2	15.2
TOTAL	31.4	4.3	3.9	5.5	13.7	45.1	6.8	51.9
Procurement by Source of Production								
Domestic	20.5	2.6	2.5	3.4	8.5	29.0	4.8	33.8
Imports								
US	n.a.[c]	0.05	0.35	0.1	0.5	0.5	1.3	1.8
Europe	0.1	0.05	0.15	0.3	0.5	0.6	0.5	1.1
Total Imports	0.1	0.1	0.5	0.4	1.0	1.1	1.8	2.9
TOTAL	20.6	2.7	3.0	3.8	9.5	30.1	6.6	36.7
Arms Deliveries by Customer								
Own Forces	20.5	2.6	2.5	3.4	8.5	29.0	4.8	33.8
Exports								
Industrial Countries[b]	1.8	0.3	0.5	0.2	1.0	2.8	0.1	2.9
Non-Industrial Countries	7.7	2.5	0.1	1.5	4.1	11.8	0.9	12.7
Total Exports	9.5	2.8	0.6	1.7	5.1	14.6	1.0	15.6
TOTAL	30.0	5.4	3.1	5.1	13.6	43.6	5.8	49.4

[a]Other NATO countries, non-communist European countries outside NATO, plus Australia, Japan, and New Zealand.

[b]Includes US, France, FRG, and UK plus countries listed in footnote a.

[c]Not applicable.

Source: References [1-16] of Chapter II.

In examining imports more closely, we see that the US and France each imported about $100 million, while the UK and FRG imported $400 and $500 million, respectively. For FRG this was about 20 percent of its own force equipment, the largest percentage of imports for any of the four countries. Exports show more variation. The French exported $2.8 billion in arms which was $200 million more than they bought for their own forces. Although US exports were higher, $9.5 billion, it was less than one-third of production, about the same proportion as the UK. FRG exports were lowest, $600 million or about one-sixth of total production. A possibly higher FRG figure is somewhat disguised because West Germany participates in consortia with other countries that are heavily engaged in selling arms.

Also note that sales outside the Western Alliance accounted for one-quarter of output. The importance of such sales suggests that for many weapons which were duplicated within the Alliance, the duplication may have been to satisfy a potential market outside the Alliance, rather than for arming NATO. For example the related French short range air defense systems Crotale and Shahine were developed for South Africa and Saudi Arabia, respectively.

Looking next at the state of arms trade within the Alliance during the period 1973-1977, we see relatively small amounts of trade among the major powers (see Table S-5). The US sold over $1 billion to the medium NATO European powers (Belgium, Denmark, Italy, Netherlands, and Norway) while France, FRG, and UK, together, sold just under $500 million. This imbalance will become even greater when the 1975 sale of F-16 fighter aircraft results in substantial deliveries in the 1980s. It is this particular imbalance which is most troubling to major European producers. Indeed, it has led to the formation of the Independent European Program Group (IEPG) whose purpose is to allow for French participation in a military equipment forum which was for the European NATO countries, but was without formal ties to NATO.

Table S-5. ARMS TRADE BETWEEN US AND NATO EUROPE AND WITHIN NATO EUROPE, 1973-1977

(Millions of Dollars)

Importers	Exporters						
	US	Major European				Medium European[a]	Total Imports
		France	FRG	UK	Total		
US	--	0	30	320	350	25	375
Major European							
France	155	--	0	0	0	5	160
FRG	1,705	400	--	90	490	300	2,495
UK	600	30	0	--	30	20	650
TOTAL	2,460	430	0	90	520	325	3,305
Medium European[a]	1,002	160	190	130	480	100	1,582
TOTAL EXPORTS	3,462	590	220	540	1,350	450	5,262

[a]Medium NATO European producers and consumers: Belgium, Denmark, Italy, Netherlands, Norway. These five countries buy their own arms and are, therefore, of greater importance as customers to the major producers. Greece and Turkey have not been included because the bulk of their imports continues to be supported by a combination of aids and loans. Canada's arms imports and exports exceed that of any of the medium European producers and consumers, but her arms trade is almost entirely with the US and not transatlantic, the issue we are emphasizing along with intra-European trade.

Source: Reference [19] of Chapter II.

C. EUROPEAN VIEWS OF COOPERATION

The European views of weapons cooperation are quite straightforward and have been expressed by their leading political and military spokesman in public statements on both sides of the Atlantic. With minor exceptions, these views are consistent with those offered in private and reported by writers and researchers on both sides of the Atlantic.

The major European arms producers (France, FRG, and the UK) advocate pursuing policies of arms development and production that will assure political independence, economic and technological strength, and internal political support for defense spending. The officials of these countries have stressed--in policy statements, in speeches to European audiences and in

speeches to American audiences--the following objectives of their arms program:

(1) access to a supply of a full line of weapons without political limitations;

(2) cooperative programs with major European Allies in multilateral agreements but more likely in bilateral agreements;

(3) acceptance of a "transatlantic dialogue" with the US and Canada provided that such dialogue

  (a) is based on European participation as an equal partner,

  (b) does not interfere with intra-European cooperation,

  (c) involves increased direct purchase by the US of European systems, or at least adoption by the US of such systems through the use of licenses, and

  (d) does not interfere with sales to other countries;

(4) increased interoperability of equipment without a requirement for a single standardized Alliance weapon-system.

These aims are seen to allow the Europeans to preserve political independence and to continue their current employment levels in their arms industries, maintain development work in advanced technology, improve manufacturing technology, and use arms sales for balance of payments and political purposes. There is some question about whether the broad aims of their program can be achieved by the more specific objectives; for example, whether there are significant economic benefits from weapons research. What is important, however, is that the Europeans believe these benefits exist. Indeed, US defense authories use similar arguments in support of specific programs and cite such general benefits as one of the *offsets* against high overall defense budgets, though never as the *justification* for an arms industry.

D. TACTICAL MISSILES

Because the family of weapons approach to arms cooperation has focused almost exclusively on tactical missiles (though excluding some) our study surveyed the tactical missile field to determine to what extent conditions for cooperation exist and to determine what potentials for savings exist if cooperation eliminates duplicative development efforts.

Since World War II, the major powers in NATO have developed 77 different weapons in the six major tactical missile types (Table S-6). If the two major European developers of tactical

Table S-6. NUMBER OF NATO TACTICAL MISSILE BY COUNTRY AND TYPE

	Type												All Types		
	Surface-to-Air (land)		Surface-to-Air (sea)		Air-to-Air		Anti-Tank		Air-to-Surface		Surface-to-Surface				
Period	US	Europe	US	Europe	US	Europe	US	Europe	US	Europe	US	Europe	US	Europe	Total
1949-53	1	0	1	0	0	0	0	0	0	0	0	0	2	2	2
1954-58	3	3	2	0	3	3	0	3	0	0	0	0	8	9	17
1959-63	0	1	0	3	0	1	0	2	2	3	0	0	2	10	12
1964-68	2	3	2	1	0	1	1	2	2	1	0	0	7	8	15
1969-73	1	1	0	0	1	0	2	2	2	0	0	1	6	4	10
1974-78	0	1	1	1	0	2	0	1	1	2	1	1	3	8	11
1979-	3	1	0	0	0	1	1	0	2	1	1	0	7	3	10
TOTAL	10	10	6	5	4	8	4	10	9	7	2	2	35	42	77

Source: Appendix C. This table is identical to Table 18. It includes guided projectiles and bombs such as Copperhead and the GBU-15 family. It excludes weapons designed and deployed primarily as nuclear weapons such as Lance and Pershing.

missiles--France and the UK--had completely duplicated the US efforts, the European total would have been about double the US total of 35. Instead, we count only 42 European systems. The numbers (shown by five year periods) indicate continuing European effort in all six types but with a drop-off in the last few years. Not shown in the table is the increase in intra-European cooperation. Whereas only 1 of 27 European weapons was developed cooperatively through 1968, 5 of 15 have been developed cooperatively since that time.

Based on an analysis of tactical missile development since World War II, we find the Europeans have abandoned to the US--since the 1950s--the theater-oriented weapons types. This includes the longer range anti-aircraft missiles both surface-to-air and air-to-air as well as air-to-ground weapons that are oriented to area action. However, the Europeans have displayed continuing interest in strike fighters capable of interdiction missions and possible nuclear delivery (e.g., MRCA).

To get a quantitative view of this emphasis we calculated--for six weapon types--seven ratios of European/US interest and capability (Table S-7). Based on those measures, we found

Table S-7. MEASURES OF EUROPEAN TACTICAL MISSILE INTEREST AND CAPABILITY BY TYPE

(Value of US Measure = 1.00)

Missile Type	Value of Measure for UK, France, FRG Combined						
	Number of Different Weapons		Estimated R&D Expenditures	Units Produced		Demand as Sized by Own Forces	Prime Contractors
	Developed	In Production 1980s		1949-1978	1978		
Surface-to-air (land)	0.90	1.25	0.40	0.19	0.40	0.85	0.71
Surface-to-air (sea)	0.83	0.50	0.82	0.79	0.27	0.64	2.00
Air-to-air	2.00	1.00	0.85	0.17	0.46	0.52	0.75
Anti-tank	2.50	2.00	2.27	1.33	0.63	0.85	0.75
Air-to-surface	0.89	1.00	0.65	0.08	0.12	0.61	1.00
Surface-to-surface (sea)	1.00	2.00	1.77	0.86	1.25	0.46	0.50
Overall Measure	1.17	1.11	0.75	n.a.	n.a.	n.a.	0.64

Source: Chapter V. See Table 24 for details.

general US dominance in four of the six types for which measures could be obtained. The measures included number of weapons, estimated development spending, units produced, exports, requirements for own forces, and number of prime contractors.

In anti-tank and surface-to-surface anti-ship weapons, one finds that European development effort and output match US figures. Looking at a more detailed level than that shown

in the table would add the short range land-based air defense system to the list of those with strong European interest and capability.

US dominance in the broader category of land-based air defense derives from its spending and production of high altitude long range air defense systems confirming that the Europeans have largely abandoned the field of theater and area weapon systems.

Finally, we examined how much might have been "saved" in R&D to provide a program of roughly equal capability and timeliness if a cooperative system had been in operation over the last 30 years. The "saving" being estimated is based partly on historical costs of development programs judged to be redundant, but primarily upon parametric estimates of the cost of such programs. We estimated a spending total of $64.2 billion (in 1979 dollars) including aborted developments (Table S-8). We then specified

Table S-8. ESTIMATED REDUNDANT R&D SPENDING ON NATO TACTICAL MISSILES
(Billions of 1979 Dollars)

Category	All Spending	Redundant Spending	
		Dollars	As a Percent of Total Spending
Completed Projects			
Surface-to-air (land)	8.4	2.3	3.6
Surface-to-air (sea)	3.2	1.4	2.2
Air-to-air	4.3	2.5	3.9
Anti-tank	3.0	1.7	2.6
Air-to-surface	3.3	1.7	2.6
Surface-to-surface	1.9	0.8	1.2
Total Completed	24.1	10.4	16.2[a]
Aborted Projects	8.0	3.5	5.5
Total All Projects	32.1	13.9	21.7
Infrastructure	32.1	13.9	21.7
TOTAL	64.2	27.8	43.3[a]

[a]Does not add because of rounding.
Source: Chapter VI.

specified a "minimum" program that would have been necessary to produce the smallest set of missiles which would have met NATO

operational requirements. The remaining missiles were considered, for these purposes, to be redundant. Using this procedure, we estimated redundant spending at $13.9 to $27.8 billion over the 30 year period or 21.7 to 43.3 percent of the total. This amounts to about $450 to $900 million per year. The range depends on what one assumes about how much of the missile related R&D infrastructure--that is, technology base research and development work not related to specific programs--might have been eliminated along with the redundant programs. In particular, in the higher figure we assume a proportional cut in infrastructure and in the lower figure we assume no cut in infrastructure. Needless to say, these figures are for gross comparison purposes only--the actual (and practically unknowable) accounting costs would reflect the complex considerations, often unique, of specific programs, countries, and technological histories. Moreover, no attempt was made to estimate the impact of such a program on production or logistics costs.

No judgment was made about the feasibility or realism of such a program from a political point of view. Indeed, the evidence we present would suggest that such a program in peacetime among the sovereign nations of NATO was all but impossible to attain. However, in recent years cooperation has increased. Thus, when we look to the future, we find redundancy or potential additional savings--in the area of tactical missiles--limited to about $250 to $500 million per year (in 1979 dollars) out of about $2 billion per year. Again, the range of savings is based on different assumptions about infrastructure cut backs.

The reasons for the lower potential for additional savings in the future are: (1) the most expensive weapons, i.e., the theater oriented air defense both surface-to-air and air-to-air weapons and the theater oriented air-to-ground weapons, appear mainly to have been left to the US by the Europeans; and (2) the Europeans are already cooperating among themselves on many

types of tactical missiles. Nonetheless, the increasing complexity of missiles and the proliferation of new types have offset, to some extent, this increasing intra-European cooperation.

To put the missile cost savings in perspective, estimates of the proposed program for development of a European tactical aircraft for the 1990s are in the range of $3.5 to $6 billion or about $350 to $600 million per year. Elimination of that one development program would save about as much as the savings from the elimination of all the potentially redundant tactical missile programs.

E. FINAL COMMENTS

There are major impediments to cooperation on both sides of the Atlantic. The US system for planning and acquiring weapons would require major adjustments in order to permit extensive engagement in international cooperative development and production efforts. European (France, FRG, UK) policy demands equality before engaging in cooperation and seeks to exclude US participation in the European market as much as possible.

European interest and capability in producing many types of tactical missiles is quite limited. Nevertheless, there are areas where their strategic interest and their forces have led them to compete on an equal or close to equal footing with the US. We found three such areas--short range (land-based) air defense, anti-tank, and surface-to-surface anti-ship missiles.

Given the difficulty with cooperation on both sides of the Atlantic and the modest proposals for eliminating competitive development programs, only limited gains are possible from cooperation that concentrates on tactical missiles as does the family of weapons approach. By excluding the most expensive and complex missiles--the land-based high to medium altitude air defense systems--and by excluding other major weapons, particu-

larly aircraft, the family of weapons promises less than does coproduction of standardized weapons, which is likely to remain the most significant approach to armaments cooperation.

The weapon by weapon approach to cooperation is now the policy of all the NATO countries--and is characteristic even of the family of weapons. Each weapon or limited agreement must stand on its own and overcome many impediments on both sides of the Atlantic. Thus, the broader benefits of arms cooperation are not easily demonstrable. These broader benefits of freer arms trade might come from a wide-ranging multilateral arms trade agreement on the model of the Multilateral Trade Negotiations (MTN) just completed among the major trading nations of the West. But such an approach would be successful only if the US, France, FRG, and the UK are willing to accept increased interdependence in arms development, production, and trade. If this is not true, as appears from current policies, then the present system of limited and ad hoc cooperation will continue to dominate US/European arms agreement and will continue to be the major route to standardizing NATO weapons, with substantive progress in that regard likely to come quite slowly.

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Chapter I

APPROACHES TO COOPERATION IN WEAPONS DEVELOPMENT AND PRODUCTION

The US spends about $13 billion per year on R&D; the other NATO nations together spend $4 to $5 billion. Much of this spending is thought to be redundant since equivalent weapons are developed by a number of different nations. Two problems are created: money is spent on the redundant development; and many non-standardized systems are spread through NATO forces, increasing the cost of acquiring and operating the systems and decreasing their effectiveness in the field.

This development work is necessarily redundant only if the purpose of this $17 or $18 billion of total R&D funding is to provide an efficient defense for some specific and agreed upon set of NATO missions. However, the three major NATO arms developers--France, the UK, and the US--all have other responsibilities outside the defense of the German border against Warsaw Pact attack. Even for those missions which are common, the methods of carrying them out are not agreed upon. In addition, all three countries export a substantial share of their weapons outside NATO and much of their development programs is aimed at these external markets. Other goals of development programs include employment, economic benefits of advanced technology, and the protection of domestic industries to improve balance of payments.

Even if there is no agreement on the purposes to be served, some R&D funds may be saved and some advantage gained by partial agreement. The thrust of the US initiative in cooperative

development is to stretch the limited R&D budgets of the major NATO nations and to spread identical weapons systems through the NATO forces. The US proposes two methods of doing this: (1) licensing the coproduction of already developed systems; and (2) the "family of weapons" concept by which the US and the Europeans would specialize in development within mission areas, with cross-licensing for production. Separate agreements would be made in each mission area, with most of the proposed agreements covering pairs of weapons--one to be developed by the Europeans.

A third possibility is to combine a number of areas into a more comprehensive agreement. Such an agreement would allow tradeoffs across missions, technologies and vehicle types to balance the complex military, economic, political, and technological interests involved in weapons development and procurement.[1]

A. LICENSING AND COPRODUCTION

The simplest approach to saving development money is to license already developed systems. In a licensing agreement, one party agrees to supply a data package and technical help to the other. The licensed producer--which may be from one or several countries--then produces the weapon systems, agreeing to pay a license fee as well as any additional expenses incurred by the developer in the process of transferring technology in supporting production. The licensee typically also agrees to limitations on sales of licensed-produced systems to third countries.

License agreements may involve 100 percent duplication of production facilities as in the case of the US production of the

[1]Such an approach has been espoused by the leading exponent of NATO arms cooperation, Thomas A. Callaghan [1, pp. 57-64] and more recently by Ellen Frost, Deputy Assistant Secretary of Defense for International Economic Affairs [2].

Roland air defense system. Alternately, the licensing country may produce some components because it is unwilling to transfer all the manufacturing technology. Thus, the US is producing some components of the Sidewinder (AIM-9L) air-to-air missile and of the MODFLIR (modular forward-looking infrared) electronics.

Other agreements, such as those for the F-16 fighter and AWACS early warning radar aircraft, are coproduction and offset agreements wherein the country purchasing the system is involved in an integrated production arrangement with the country that developed the weapons. In the AIM-9L licensing agreement, the European production of the missile is by an internation consortium led by an FRG producer aided by the original developer. In a coproduction agreement, such as for the F-16, the US and European production is done together in a consortium led by the firm that developed the weapon.

The "offset" is the guarantee by the weapon developer that enough business will go to the other countries to equal some agreed upon percentage of the cost. These agreements are meant to protect jobs and foreign exchange positions even though they add to the cost.

Whether the agreement is one that licenses the complete system, licenses part of the system, or coproduces the system with a consortium, its purposes are the same: to make it unnecessary to develop the same weapon in two or more countries and to provide for standardized equipment in the field once the weapon is produced.

Although coproduction and offsets are not included in DoD statements on NATO standardization as a major thrust of the US program, it is clear that such programs outweigh all others in terms of their significance. The F-16 fighter aircraft and the AWACS early warning aircraft are two of the most expensive

four or five weapons programs currently in progress in the European NATO countries. A third major program, Patriot air defense system, is being negotiated for license or coproduction. In neither of the first two cases were funds saved from eliminating duplicate development programs, since competitive development programs had already taken place or were never proposed. A European development program competitive with Patriot is under preliminary discussion in Europe.

Objections to dependence on licensing and coproduction to achieve weapons standardization revolve partly around the fact that this approach fails to solve the problem of duplicate development. Once a system is developed, positions are hardened on military requirements, business and labor expectations arise which will be disappointed, and generally there are too many vested interests to allow a government to choose a foreign-developed system. Thus, the major thrust to save development money has centered on the family of weapons.

B. FAMILY OF WEAPONS

The family of weapons concept has been described officially by Dr. Perry (USDR&E) as follows [3, pp. 8-9]:

> Our approach is to examine the weapons by mission area. When we find two or three that perform similar missions, we will agree to divide the responsibility. For example, one party would develop a long-range air-to-air missile and the other a short-range version. We would anticipate such divisions to be made among the U.S. and Canada on the one hand and European consortia on the other. Each nation would fund the program for which it is responsible.

Dr. Perry goes on to include other aspects of the family of weapons proposal [*ibid.*]:

> (1) Transatlantic subcontracting of a portion of the development of each system.

(2) Competitive selection of US prime contractors, US subcontractors, and European subcontractors for all systems for which the US is responsible.

(3) Once development is complete the developing nation or consortia will make available to the other participants a production data package so that two production lines can be established.

The treatment of technology transfer, competitive developments, and third country sales were left ambiguous, but elsewhere the issues have been treated as follows [4, pp. 702-703].

(4) The transfer of data would be on an industry-to-industry basis with appropriate government guidelines and incentives.

(5) The parties would agree to terminate competitive developments, i.e., the US would not develop a system to serve the function of a European-developed system and vice versa.

(6) Arms transfer to other countries would be restricted where national security could be compromised. There would be no restrictions on sales to NATO or Allied countries.[1] Unanimous agreement would be required for other sales.

The families currently under discussion are weapon types rather than missions. These weapon types include air-to-air missiles, anti-tank guided missiles, air-to-surface weapons and anti-ship missiles, with torpedoes and mines also being mentioned as separate families [*ibid.*]. Other weapon types mentioned more recently as "fruitful areas for addressal as a 'family'" have included fire support, mobility-counter mobility, naval mines, battlefield surveillance, and shipboard defense [5, p. 245].

Air defense missiles have been excluded from the family of weapons. According to Dr. Perry "Most of the activities in this field (Roland, Patriot, Stinger, EURO-SAM study) were already under way before the [family of weapons] concept appeared

[1]Presumably "Allied" refers to Australia, Japan, and New Zealand but possibly also Sweden and Switzerland.

on the scene. Hence, most of the air defense programs will be coproduction or dual production rather than codevelopments."[1] Similarly excluded are all aircraft--fixed wing and helicopters [6, pp. 32,37, and 38].

Although discussions are proceeding on air-to-air and anti-tank missiles, little progress has been made in other weapon areas [6, p. 26]. An agreement or "memorandum of understanding" incorporating the broad principles of the family of weapons (summarized in Table 1) has been suggested by the Defense Science Board[2] but negotiations have not yet begun.

Table 1. PRINCIPLES OF FAMILY OF WEAPONS

INITIAL PLANNING
Aggregate weapons by mission.
Divide responsibility for two or three weapons that perform similar missions.
Divide work on a transatlantic basis.
Write separate MOUs for each mission.
DEVELOPMENT
Responsible country or consortia will pay for development.
Transatlantic subcontracting.
Competitive selection of contractors for US/Canada improvements.
Eliminate engineering development that would result in competitive weapon although "product improvements" are to be exempted.
PRODUCTION
Make available production data packages for two production lines.
Technology transfer across Atlantic on an industry-to-industry basis.
Restrict third country sales according to current US policy.

[1]The quotation is indirect, taken from [4, p. 703].

[2]The two Defense Science Board papers [7] and [8] are the most comprehensive and detailed studies of the family of weapons concept. Neither endorses such an approach but they show what sort of an agreement would be necessary if such an approach is to be implemented.

C. ARMS EQUIPMENT POLICIES: US CONSTRAINTS

The US approach to arms cooperation is to stress cost and effectiveness of NATO weapons as if the Alliance were a single sovereign nation (cf. [9]). In fact, there are a number of other criteria pursued by the European nations involved (to be discussed in Chapter III); but there are also internal problems for the US in pursuing NATO standardization through weapons cooperation.

In particular, the US decides on, plans for and buys weapons systems under a rather elaborate and stylized system that involves many constraints. This system has procedures and regulations which are five years old, others date back to the early sixties, others to the second world war, and still others--the prerogatives of the Congress to authorize and appropriate funds--date to the Constitution itself. Some of the procedures and approaches are largely internal DoD procedures, others are a matter of Federal policy outside the direct control of DoD, and still others are matters of law that can be changed only with the consent of the Congress. All these were put in place to achieve some goal, which will necessarily be compromised if exceptions are made for NATO cooperation. Without discussing the merits of such compromises, their costs must be considered in any agreement.

These institutional constraints can be divided into (1) those that involve the formal process of choosing and funding weapons and (2) other laws, regulations, and policies that govern or affect their acquisition and use (Table 2). These constraints are in place for specific reasons which were thought appropriate when instituted. Violating these constraints on a case-by-case basis to advance the cause of NATO cooperation might call each constraint into question as it applied to other programs. For example, OMB circular A-109--Acquisition of Major Systems--is now the basic document governing DoD, and indeed all Federal acquisition. If the systematic acquisition procedures

Table 2. US INSTITUTIONAL CONSTRAINTS ON NATO ARMS COOPERATION

PLANNING, PROGRAMMING, AND BUDGETING PROCESS FOR DEVELOPMENT, REVIEW, AND APPROVAL OF DOD SPENDING
Strategy
Doctrine
Acquisition
Programming
Annual Budget Review
Congressional Review
LAWS, REGULATIONS, POLICIES AFFECTING GOVERNMENT ACTION
Technology Transfer
National Security
Source Selection
Anti-trust
Accounting and Auditing
Design to Cost
Value Engineering
Producibility
Operational Test and Evaluation
Arms Transfers

prescribed by A-109 were to be excepted for European-developed weapons or for US-developed weapons which were promised to the Europeans, then the A-109 procedures for all systems could easily be called into question.

Perhaps most important, because they are so basic to the arms cooperation concept, are the problems of technology transfer, security, and arms transfers to countries outside the industrial free world.

The current US policy on technology transfer is ambivalent. On the one hand, our NATO policy is to make available for license as much as possible to our NATO Allies within the bounds of US laws, policies, and procedures. On the other hand, there is a growing fear that we are exporting too much advanced manufacturing technology. In 1977, for example, the U.. received

$2.95 billion in licensing fees and royalties from abroad while purchasing $282 million [10]. Without going into the merits of arguments that such transactions will eventually destroy our leadership in technology, it is clear that many believe these arguments to be correct.

In addition, there is a security concern that technology sold or given away will eventually reach the USSR. The concern about limiting the licensing of "critical technologies" is extended even to our Allies by some critics. Thus, attempts to transfer such technology are likely to meet road blocks erected by those people entrusted with protecting the security of information.[1]

Finally, there is the conflict between the US policy of limiting arms sales to the non-industrial nations and our licensing of US weapons for European production. The US exercises its right to veto individual sales by licensees of US weapons to third countries. Even simple transfers of (almost obsolete) US arms between NATO Allies is subject to approval by the US government.

Although it apparently has not been recognized (or even acknowledged), the proposed limitation of the family of weapons policy, which would require consent of the licensing government(s) to sell outside specified areas, would be as great a restriction on US foreign policy as on British, French or German policy. Thus, the air-to-air family of weapons agreement, as now proposed, would have the US licensing a short range air-to-air missile from the Europeans in the 1990s and the US developing and licensing a medium range missile for European production. If this agreement were consummated within the limitations that the US has proposed, then the US would not have--in the 1990s--an advanced short range missile to sell to its Allies without the

[1]The recent crisis in Afghanistan and the subsequent review of US agreements with the USSR show how quickly policy in this area can be changed.

permission of all three European countries. Similarly, the Europeans would not be able to sell their most advanced medium range missile without US permission. In fact, the Europeans would have a considerable commercial and political advantage since the short range missile will be of more interest to non-NATO Allies and arms customers.

The problem has other subtleties. Consider the possibility of British and French sales to China. In a formal sense there is little the US can do to stop them. But if France and the UK required US permission for sales of some advanced weapons, even though manufactured by France or the UK, then the US would be a party to such sales in the eyes of any country that disapproved of the sales. This would be particularly the case if the US was making a point of vetoing such sales to some countries, as it has in recent years.

Where many of the other problems involve compromises within DoD on relatively minor procedural issues, three of these--technology, transfer, security and particularly arms sales--go to the heart of any agreement. More technology transfer, less stringent security and easier arms sales limitations will improve the prospects of cooperation but will compromise other important policies.

D. PROSPECTS FOR COOPERATION

In the remainder of this paper we discuss those issues that bear on the prospects for standardization through agreements for cooperation in development and production and, in particular, the prospects for the family of weapons concept as now conceived. We confine most of our examination to the US and the three major European powers--France, the FRG, and the UK--who, along with the US, dominate NATO in terms of spending levels, weapons production, and force levels.

The R&D and acquisition programs of the major NATO powers should serve the same objectives, and contributions to cooperative programs should be roughly proportional to overall contributions. In Chapter II we address defense budgets, arms imports and exports, and R&D on an aggregate level and we look at the nature and level of existing cooperative arms agreements among the NATO countries.

As discussed in the last section, US policy on cooperation is constrained by its own policies, procedures, and laws, some of which conflict directly with the policy of cooperation and some of which must be adjusted to be consistent with corresponding European policies, procedures, and laws.

The existence of these conflicts is not surprising. Cooperation in weapons acquisition is a policy designed to increase the interdependence of the NATO nations and particularly the four powers. But where US or at least DoD officials publicly support interdependence--whatever internal opposition they may face--the European public stance is to oppose such a policy. It is the publicly stated European views on NATO arms cooperation that we will examine in Chapter III.

In the specific mission areas proposed for cooperation, the interest--as revealed through development projects and spending--should be consistent with proposals for cooperation. The family of weapons proposal has been targeted on tactical missiles in which the Europeans are reputed to have wide interest and capability [11, pp. 113-114 and 12, pp. 5-11]. We examine all types of tactical missiles, excluding only those that are primarily nuclear armed weapons. We look (1) for interest by mission and by type of missile, and (2) for capability, as implied by past experience, in development and production including contractor experience. One by-product of this examination is an estimate of the cost of past duplicate programs.

In Chapter IV we discuss the history of NATO tactical missile development and show how this information can be used to demonstrate mission interest. In Chapter V we present the data which show the relative and absolute interest in missiles for the four major NATO countries, based on development spending, production, exports, and force levels. This will tell us how extensive European interest and capability is likely to be in pursuing the family of weapons. Chapter VI presents the cost methodology for the calculations shown in the previous chapter and the savings that could have been realized from some extreme forms of cooperation, and projects the potential savings for the next 10 years based on plans for replacing current systems.

The final chapter presents conclusions based on our analysis, with some suggestions for why it is necessary to begin exploring a more comprehensive agreement if significant gains are to come from NATO arms cooperation.

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[3] William J. Perry, *The Department of Defense Written Statement on NATO - Improved Armaments Cooperation*, statement to the 96th Congress, 1st Session, April 4, 1979.

[4] Rudi Muller, "Pentagon Endorses Family of Weapons Concept," *International Defense Review*, May 1979, pp. 702-707. This article is based on interviews with Dr. Perry and Dr. V. Garber. They are quoted directly in some cases and indirectly in others.

[5] *Department of Defense Appropriations: Fiscal Year 1980*, Committee on Appropriations, US Senate, 96th Congress, 1st Session, Part 4 - Procurement, RDT&E, GPO, Washington, DC, 1979.

[6] *Meeting Report, International Conference on Defense Cooperation*, American Defense Preparedness Association, Washington, DC, January 31 - February 1, 1980.

[7] Walter B. LaBerge and O.C. Boileau, *Summary of the Defense Science Board Summer Study on "Achieving Improved NATO Effectiveness Through Armaments Collaboration,"* 31 July - 11 August 1978, Naval War College, Newport, Rhode Island, Defense Science Board, Office of the Under Secretary of Defense for Research and Engineering, December 1978.

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[11] Robert Komer, "Looking Ahead," *International Security*, Summer 1979, pp. 108-116.

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Chapter II

ARMS EQUIPMENT POLICIES: THE CURRENT SITUATION

A. AN AGGREGATE VIEW OF ARMS BUDGETS, IMPORTS, EXPORTS, AND INDUSTRIAL ACTIVITY

Of the $64.6 billion total defense R&D and production in the Western developed countries in 1978, the US was responsible for $40.8 billion (Table 3). The US provided over 60 percent of the production ($30 out of $49.4 billion). Limiting ourselves to the countries of primary interest in this study--the US, France, FRG, and the UK--the US provided approximately 70 percent of both the $43.6 billion production and the $15 billion of research and development.

Table 3. ARMS EQUIPMENT FOR WESTERN INDUSTRIAL COUNTRIES, 1978
(Billions of Dollars)

Category	Four Powers						Other Western Industrial Allies	Total Western Developed
	US	Major European				Total		
		France	FRG	UK	Total			
Production	30.0	5.4	3.1	5.1	13.6	43.6	5.8	49.4
R&D	10.8	1.6	0.9	1.7	4.2	15.0	0.2	15.2
TOTAL	40.8	7.0	4.0	6.8	17.8	58.6	6.0	64.6

Source: Table S-4.

The production of these four countries was not just to arm NATO and other industrial Allies that face the USSR. Of the $43.6 billion in four power arms production, $11.8 billion went to the developing or non-industrial countries of the world

(Table 4). Thus, the R&D of the major producers provides the weapons for NATO and the other developed countries, as well as weapons for countries with different problems of defense and--perhaps more important--different capabilities to support sophisticated weapons.

Table 4. EQUIPMENT EXPENDITURES, PROCUREMENT BY SOURCE OF PRODUCTION, AND SALES BY CUSTOMER--WESTERN INDUSTRIAL COUNTRIES, 1978

(Billions of Dollars)

Category	Four Powers						Other Western Industrial Allies[a]	Total Western Developed
	US	Major European				Total		
		France	FRG	UK	Total			
Equipment Expenditures								
Total Procurement	20.6	2.7	3.0	3.8	9.5	30.1	6.6	36.7
R&D	10.8	1.6	0.9	1.7	4.2	15.0	0.2	15.2
TOTAL	31.4	4.3	3.9	5.5	13.7	45.1	6.8	51.9
Procurement by Source of Production								
Domestic	20.5	2.6	2.5	3.4	8.5	29.0	4.8	33.8
Imports								
US	n.a.[c]	0.05	0.35	0.1	0.5	0.5	1.3	1.8
Europe	0.1	0.05	0.15	0.3	0.5	0.6	0.5	1.1
Total Imports	0.1	0.1	0.5	0.4	1.0	1.1	1.8	2.9
TOTAL	20.6	2.7	3.0	3.8	9.5	30.1	6.6	36.7
Arms Deliveries by Customer								
Own Forces	20.5	2.6	2.5	3.4	8.5	29.0	4.8	33.8
Exports								
Industrial Countries[b]	1.8	0.3	0.5	0.2	1.0	2.8	0.1	2.9
Non-Industrial Countries	7.7	2.5	0.1	1.5	4.1	11.8	0.9	12.7
Total Exports	9.5	2.8	0.6	1.7	5.1	14.6	1.0	15.6
TOTAL	30.0	5.4	3.1	5.1	13.6	43.6	5.8	49.4

[a]Other NATO countries, non-communist European countries outside NATO, plus Australia, Japan, and New Zealand.

[b]Includes US, France, FRG, and UK plus countries listed in footnote a.

[c]Not applicable.

Sources: References [1-16].

We note--still looking at data for 1978 (Table 5)--that the US and France equip their forces almost entirely (96 to nearly 100 percent) with domestic arms, the UK somewhat less (89 percent), and the FRG least, but still providing 83 percent of its equipment from domestic sources. Still using 1978

Table 5. PERCENTAGE DISTRIBUTION OF VARIOUS CATEGORIES OF DEFENSE SPENDING AND TRADE BY COUNTRY, 1978

Country	Defense Equipment Budget		Source of Equipment for Own Forces		Destination of Production			Defense Industrial Activity	
	Acquisition	R&D	Domestic	Foreign	Own Forces	Exports to Industrial Countries	Exports to Non-Industrial Countries	Production	R&D
US	66	34	100	--[a]	68	6	26	74	26
France	63	37	96	4	48	6	46	77	23
FRG	77	23	83	17	80	16	4	78	22
UK	69	31	89	10	63	7	30	75	25

[a]Less than 0.5 percent.

Source: Tables 3 and 4.

figures, the US and UK export about one-third of their production, 32 and 34 percent, respectively; the FRG exports only 20 percent; while France exports over half, 52 percent. Further, looking at the destination of exports, we see that 46 percent of the total French production goes to countries outside the industrialized West.

If we examine the split between production and R&D--not within the defense budget, but for the whole arms industry (including in-house R&D and production)--we see that all four countries are quite close: 22 to 26 percent of their work in R&D, rather than the range of 23 to 37 percent of their defense budgets in R&D. This may be happenstance, but perhaps the 25 percent can be thought of as a kind of norm. Then the R&D programs of each of the four countries should be considered to be supporting not only production for its own forces, but production for its overseas customers--both within and outside the Alliance.

B. ARMS TRADE AND COOPERATION AMONG THE MAJOR PRODUCERS

The significant aspects of the NATO arms trade are the low level of such trade within NATO, the US dominance as a producer, developer and exporter and, finally, the sporadic and limited

nature of arms cooperation. It is from this base that any policy on arms cooperation must be built.

Looking first at the arms trade among the four powers from (calendar years) 1973-1977, the US delivered about \$2.5 billion in arms to the other three major NATO arms producers and bought about \$350 million worth (Table 6).[1] But France, even more

Table 6. ARMS TRADE BETWEEN US AND NATO EUROPE AND WITHIN NATO EUROPE, 1973-1977

(Millions of Dollars)

Importers	Exporters: US	Major European: France	Major European: FRG	Major European: UK	Major European: Total	Medium European[a]	Total Imports
US	--	0	30	320	350	25	375
Major European							
France	155	--	0	0	0	5	160
FRG	1,705	400	--	90	490	300	2,495
UK	600	30	0	--	30	20	650
TOTAL	2,460	430	0	90	520	325	3,305
Medium European[a]	1,002	160	190	130	480	100	1,582
TOTAL EXPORTS	3,462	590	220	540	1,350	450	5,262

[a]Medium NATO European producers and consumers: Belgium, Denmark, Italy, Netherlands, Norway. These five countries buy their own arms and are, therefore, of greater importance as customers to the major producers. Greece and Turkey have not been included because the bulk of their imports continues to be supported by a combination of aid and loans. Canada's arms imports and exports exceed that of any of the medium European producers and consumers, but her arms trade is almost entirely with the US and not transatlantic, the issue we are emphasizing along with intra-European trade.

Source: Reference [19].

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[1]Official figures on arms trade as shown, for example, in [17] give an inaccurate picture of the arms trade flows. In particular, some coproduction work done in European countries and US procurement of components are not shown as US purchases although they should be for consistency if they are being used to measure trade flows across the Atlantic. With these omissions, the use of ratios of US-European arms trade, based on these figures, is totally meaningless.

than the US, has been reluctant to buy arms abroad. Her trade with the other three powers was limited to $155 million in purchases, all from the US, and $430 million in sales, mostly to the Federal Republic of Germany.

The Federal Republic of Germany and the United Kingdom, on the other hand, have been willing to buy weapons from abroad that they could not or would not develop. However, the FRG purchases from the US and the UK, from the mid-1960s until 1977, have been made under an agreement by which the Germans agreed to offset US foreign exchange costs for troops stationed in Germany. Without these agreements, it seems likely that German purchases would have been lower and would have involved more coproduction and licensing arrangements under which the Germans would have bought US designs rather than US equipment.[1]

1. US-European Trade

Moving to the issue of arms trade between each of the four powers and other NATO countries, we find the US dominating the trade with five other NATO countries that purchase substantial arms with their own funds. The US delivered $1 billion in arms to those countries, compared to $480 million in sales by France, FRG, and UK to those same countries. Thus, the one way traffic across the Atlantic so often complained about by France and the UK is largely between the US and the five other European countries.

Examining recent sales--rather than delivery data as above--we see, in Table 7, $6 billion in US sales to the same five countries. Thus, US arms deliveries to the smaller countries will show a substantial increase over the next few years, due largely to the sales of the F-16 fighter aircraft to Belgium,

[1]These offset agreements were an important element in the relations between the FRG and the US and a point of friction, that may have caused the fall of a German Prime Minister in the mid-1960s [20, pp. 74-80]. Both [20] and [21] provide useful background on the offset program.

Table 7. US ARMS SALES AGREEMENTS TO EUROPE IN FISCAL YEARS TO FIVE MINOR EUROPEAN POWERS:[a] LAST FIVE YEARS COMPARED TO TOTAL SINCE 1955

(Millions of Dollars)

	1975-1979	Total 1955-1979	1975-1979 As a Percent of Total
Belgium	1,604	1,770	91
Denmark	929	1,068	87
Italy	131	794	16
Netherlands	2,206	2,426	91
Norway	1,372	1,651	83
TOTAL	6,242	7,709	81

[a]As mentioned in an earlier footnote, the official Defense Security Assistance Agency figures shown in the table are gross sales that do not reflect offset arrangements. The coproduction arrangement called for General Dynamics to subcontract 58 percent of the European F-16 cost back to the countries procuring the aircraft. This reduces the total sales figure above by $2.2 billion as of late 1979 and eventually by $2.4 billion to satisfy the original agreement [23, p. 6]. Since no similarly large sales have taken place between the five countries shown above and the three major powers, the US would dominate arms sales to these five countries even if we reduce the $6.2 billion by $2.4 billion to $3.8 billion.

Source: Reference [24, pp. 1-2].

Denmark, the Netherlands, and Norway. This US dominance will continue for a number of years due not only to the procurement of the F-16 but also to purchase of NATO early warning aircraft (AWACS) from the US.[1]

US-developed arms have dominated NATO arms transfers[2] since World War II. The early transfers were almost entirely aid—$12 billion worth through 1960 to the eight major buyers

[1]The AWACS systems will cost about $1.9 billion of which half will be paid by the Europeans (30 percent FRG and 20 percent split among the others—not including France and the UK). The North American half will be 40 percent, US, and 10 percent, Canada [22, p. 93].

[2]The term *transfer* is used to cover equipment that is transferred from one country to another as a gift, through soft loans or sold as a normal business transaction.

of arms. Since then, the transfers have been largely sales with the largest transactions occurring as part of coproduction agreements for US designed equipment. Through 1975 sales deliveries were about $9 billion with another $5.5 billion in European production of US licensed systems [24, pp. 5 and 14] and [25, pp. 19-23].[1]

US domination has not been limited to the arms market. In an industry that is close to armaments in terms of technology, the civil aerospace industry, US dominance is greater than in arms. For example, at the end of 1976 almost all the long range civil fleet, both of the US and of the rest of the non-communist countries outside the common market, was made up of US designed aircraft (Table 8). Indeed, the worldwide figure

Table 8. ORIGIN OF DESIGN MANUFACTURE, WORLD AIR FLEET THRU 31 DECEMBER 1976

(Percent of Dollar Value)

Fleet	Long Range			Short/Medium Range			Total		
	US	European	Other Western	US	European	Other Western	US	European	Other Western
US	100.0	0.0	0.0	95.0	2.9	2.2	99.0	0.6	0.4
France/FRG/UK	85.0	14.7[a]	0.3	53.0	47.0	0	71.4	28.4	0.2
Other Europe	99.8	0.1	0.2	87.1	12.6	0.3	94.2	5.5	0.2
Rest of World	99.7	0.1	0.1	75.7	22.6	1.7	89.0	10.1	0.9
World	97.5	2.4	0.1	87.3	12.0	0.6	91.9	7.7	0.4
Percentages may not add to 100 due to rounding.									

[a]This figure is made up almost entirely of Concordes built and bought by France and the UK.

Source: Reference [28, pp. 5-11].

for US designed aircraft is 97.5 percent and would have been 100 percent if not for the Concorde supersonic transport, which

[1]The bulk of the major agreements between the US and the Europeans have been for fixed wing combat aircraft and air defense systems [25, pp. 19-23]. It is these weapons that not only constitute the bulk of past US-European transactions, but also are the most expensive of US and European general purpose force development programs. Thus, they should be of special concern in future cooperation. Paradoxically their military, economic, and political importance has itself been an impediment to cooperation.

has gone out of production and out of business with 4 of 14 aircraft still unsold [26]. For short and medium range aircraft, 95 percent of the US fleet is US designed and 87.3 percent worldwide is US made. The US share for short and medium range aircraft fleets has decreased since 1976 as more and more Airbuses, built by a consortium of European manufacturers, have been sold. In 1978 the US share of the world market sales dropped to 80 percent [27, p. 655]. The success of the Airbus program does indicate that when the European producers get together and specialize--in a limited area--they can compete. But this has involved abandoning the longer range aircraft to the US. Overall, the figures indicate overwhelming US supremacy in the civil aviation market.

These figures for civil aircraft should be compared with the 60 percent US contribution to the arms production of developed western countries. Although one cannot say that free trade in arms would lead to a lower or higher figure, the evidence on civil aircraft does show that even with a (more or less) free trade regime, US aircraft have been the most successful by a large margin in this high technology area. It also dominates the market in terms of demand. This is not to say what one might expect in other arms areas. US willingness to open its market to European designs might have led to the adoption of an FRG tank. Other examples, such as wheeled combat vehicles, air defense guns, etc., might be mentioned as possibilities for US purchase of European designed or manufactured weapons.

In summary, the "imbalance" on the "two-way street" of US-European arms trade is one in which the sales to smaller European countries are predominant. In recent years the French have bought less American military equipment. The situation is similar for the UK, which bought little from the US since the mid-1960s until their recent purchases of CH-47 helicopters and submarine-launched Harpoons. The FRG may cut back on imports from the US now that the compulsion of the offset agreement no

longer exists; but because of their large inventory of US equipment, they will probably continue to buy and license US equipment for a number of years. Sales in the last five years--of $1.9 billion to the FRG and $1.2 billion to the UK--indicate the cutback has not yet occurred for either country. The major penetration of US military equipment in the European market has been the F-16 and the AWACS and their impact will carry into the late 1980s.

2. Cooperation Among the Europeans

The chief formal engine for intra-European cooperation is the Independent European Programme Group (IEPG).[1] That collection of nations lists 24 cooperative programs in various stages of development and operational use (Table 9). Separating the

Table 9. INDEPENDENT EUROPEAN PROGRAMME GROUP - COOPERATIVE WEAPON SYSTEMS[a]

Air	Jaguar Tornado Gazelle Lynx Puma Alpha-Jet Cormoran air-to-surface missile Cluster bomb BL755 Martel
Sea	Conventional submarine (developed by FRG, Netherlands, and Norway) Minehunter NATO anti-surface ship missile Exocet surface-to-surface anti-ship missile NATO Frigate
Land	CVRT 155mm FH 70 Howitzer 155mm FH 70 Howitzer on tracked vehicle Milan César/Gépard HOT Simbaline (UK/Norway) Barmine (UK/Denmark) Tactical zone transmission programme (RITA) Anti-invasion mine system

[a]Other major intra-European cooperative programs not in IEPG list include Transall transport aircraft, Roland air defense missile and Otomat anti-ship missile.

Source: [22, p. 97].

[1]The IEPG is sometimes also called the European Programme Group (EPG). See, for example, the "Report on the Activities of the Subcommittee on Defense Cooperation of the Military Committee of the North Atlantic Assembly," [22, pp. 67-100]. The North Atlantic Assembly report uses EPG throughout except on page 74.

aircraft programs for special attention (Table 10), we see that of the seven fixed wing combat aircraft being produced or about

Table 10. FIXED WING COMBAT AIRCRAFT PRODUCED OR IN ENGINEERING DEVELOPMENT IN 1979

European	
France	
Dassault-Breguet F-1c	6 for own forces 1 for export only
Dassault-Breguet 2000	
Dassault-Breguet 4000 (export only)[a]	
UK	
British Aerospace Harrier[c]	
France/FRG	
Dassault-Breguet/Dornier Alpha-Jet	
FRG/Italy/UK	
Panavia[b]/Tornado	
France/UK	
Dassault-Breguet/British Aerospace Jaguar	
US	
Marine Corps McDonnell-Douglas AV-8[c]	6 for own forces 1 for export only
Air Force Fairchild A-10	
Navy Grumman F-14	
Air Force McDonnell-Douglas F-15	
Air Force General Dynamics F-16	
Navy McDonnell-Douglas/Northrop F-18	
Export Northrop F-5 (export only)	

[a]Although the French Air Force has not ordered this aircraft, it appears to be the French candidate for the NATO combat aircraft of the 1990s [29].

[b]Panavia consists of Messerschmitt-Bölkow-Blohm, Aeritalia, and British Aerospace.

[c]Developed by UK as the Harrier with earlier US and FRG cooperation. Marine Corps is also developing its own more advanced variant for later delivery.

Source: References [1, pp. 527-528], [9, pp. 72-143], and [31, pp. 27-39].

to be produced in Europe and of the six being delivered to their forces, three have been developed cooperatively. Dassault remains outside these agreements as far as its three high performance combat aircraft are concerned, but is a participant in two others.

For purposes of comparison, the US, with three Services and many more than three missions, has developed five different types of fixed wing combat aircraft for its forces and is buying a sixth--the British-developed Harrier. Thus, even without one politically sovereign nation, the problems of gaining cooperation are not eliminated.

Other weapons areas are being undertaken under arrangements of intra-European cooperation. France and the Federal Republic of Germany have developed three tactical missile systems cooperatively, while France has developed one other missile with the UK and one with Italy. Whereas only 1 of 27 put into service before 1970 represents a cooperative effort, 5 of 15 since that date were developed by two or more countries (Table 11).

Table 11. COOPERATIVE EUROPEAN MISSILE DEVELOPMENT PROGRAMS, MAJOR EUROPEAN PRODUCERS

Missile Type	Before 1969		1969 and After	
	Total	Cooperative	Total	Cooperative[a]
Surface-to-air (land)	7	0	3	2
Surface-to-air (sea)	4	0	1	0
Air-to-air	5	0	3	0
Anti-tank	7	0	3	2
Air-to-surface	4	1	3	0
Surface-to-surface (anti-ship only)	0	0	2	1
TOTAL	27	1	15	5

[a] One French/Italian system, Otomat, is included in the total and as a cooperative European program although Italy is not included in the study as a major European producer.

Source: Appendix C, see also Table 18.

Within Europe, cooperative development has taken two main forms. When France is involved, one or the other two partners takes the lead in a rather loose association. On the other hand, the United Kingdom and the Federal Republic of Germany have been willing to enter major agreements involving a third

country and prefer a closer association with a separate management structure, such as Panavia, which was created to develop the Tornado multi-role combat aircraft.[1]

C. CONCLUSIONS

The US dominates NATO arms R&D and production. Arms exports are an important part of arms production, with France and the UK particularly dependent on sales to non-industrial countries.

The US has dominated the relatively small amount of arms trade among the four powers, selling a fair amount to the FRG and UK but buying almost no equipment from non-US sources. France sold only a small amount of military equipment while buying essentially nothing from its European partners. The US has also dominated sales to other NATO countries with the recent purchase of the F-16 fighter standing out as a singularly important transaction. However, there have been a limited number of cooperative programs among the Europeans with an increasing amount in the last decade.

The largest, most complex, and most expensive US weapons have been sold to Europeans under coproduction and licensing agreements, rather than sold as complete weapons. In a weapons related area--civil aircraft--the US finds itself dominating not only the European but also the world market in long distance aircraft. The European airbus is making some in-roads in the medium range aircraft.

Agreement among Europeans on standardized weapons is no easier than agreement across the Atlantic. Although there is some progress, Europeans find themselves developing many

[1]For discussion of preferences for these two types of organization see Reference [30, pp. 926-927]. This difference in approach between France, on the one hand, and FRG and UK, on the other, will be seen in the French government statement presented in the next chapter.

different types of aircraft and missiles with only limited--although increasing--cooperation.

With this background on the current situation, we turn now to the official views of France, the FRG, and the UK to help explain the state of NATO weapons cooperation and standardization.

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Chapter III

ARMS EQUIPMENT POLICIES: STATED VIEWS OF THE MAJOR EUROPEAN NATO ARMS PRODUCERS

The arms development and production policies of France, FRG, and the UK have been well articulated in "white papers" and in speeches by senior government officials. The stated objectives of our European Allies are generally consistent with their own actions but, unfortunately, are at variance with US policy objectives.[1] Such disagreement over objectives is unlikely to provide a sound basis for a policy of arms cooperation. Agreements which are to be expected to endure must rest on perceived mutual benefit.

The major European arms producers advocate pursuing policies of arms development and production that will assure them political independence, economic and technological strength, and internal political support for defense spending. As will be shown in this chapter, these countries have stressed the following objectives of their arms programs: (1) access to a supply of a full line of weapons without political limitations; (2) cooperative programs with major European Allies either

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[1]There are many papers outlining impediments to cooperation in NATO. The purpose of this chapter is not to repeat those papers [1-7] but rather to underscore these conflicting goals by presenting them as they are articulated by government officials of the major European NATO arms producers rather than by their interpreters. In addition, a recent unofficial view of European policy in cooperative arms development and production, given by David Greenwood [31] at the 1979 Western European Union European Armaments Policy Symposium, was so well received by the government officials there that it might be considered as a semi-official description of the European rationale and appropriate strategy for cooperation.

through multilateral agreements, if possible, but more likely through bilateral agreements; (3) acceptance of a "Transatlantic Dialogue"[1] with the US and Canada provided that such dialogue: (a) is based on European participation as an equal partner, (b) does not interfere with intra-European cooperation, (c) involves increased US direct purchase of European systems, or at least adoption of such systems through the use of licenses, and (d) does not interfere with sales to other countries; (4) increased interoperability of equipment with little, if any, emphasis on standardization.

These aims are seen to allow the Europeans to preserve political independence and to continue their current employment levels in their arms industries, maintain development work in advanced technology, improve manufacturing technology, and use arms sales for balance of payments and political purposes. There is some question about whether the broad aims of their program can be achieved by the more specific objectives; for example, whether there are significant economic benefits from weapons research. What is important, however, is that the European believe these benefits do exist.[2] Indeed, US defense

[1]The "Transatlantic Dialogue" (TAD) is the proper name given by the US to the exchange of information and proposals between the US and Canada on the one hand and the European members of NATO on the other. This exchange takes place through the Conference of National Armaments Directors (CNAD). The European inputs are supplied by the Independent European Programme Group (IEPG), an organization of countries that includes twelve European members of NATO (all but Iceland which purchases little or no military equipment) [33, pp. 3-5 and 3-8]. The Independent European Programme Group was set up because France would not participate in The Eurogroup, an organization with a formal tie to NATO [34, p. 134]. "France sets great store by the epithet *independent*...untrammelled by the familiar official structures, whether of NATO or WEU." This, according to France's leading armaments official [35, p. 21].

[2]Robert Gilpin [8] has argued that the UK concentration on defense and other high technology research for space and atomic energy has retarded that country's economic growth. Japan and the FRG are cited as examples of countries that have used advanced technology research more directly to stimulate economic growth.

authorities regularly assert that such benefits are extensive in this country.

In the remainder of this chapter, we document the European positions from their official statements and public addresses, mostly by defense ministers, national armaments directors, and major political figures in the field of armaments. Also included are statements by other defense officials that appear, in context, to be official statements of government policy. Finally, in a few cases, we use selected statements and evidence given by US and European writers who have offered policy prescriptions that are consistent with the official positions as stated by major European spokesmen.

A. THE ABILITY TO PRODUCE A FULL LINE OF WEAPONS

Although the three major European NATO countries (France, FRG, and UK) each maintain that their independence and sovereignty require control of their arms development and production, the French are clearest on the issue. In a major policy statement before the Western European Union (WEU) Ingenieur General Marc A. Cauchie, the leading French armaments official, stated the following [9, p. 1]:[1] "France maintains that the cardinal concept of national sovereignty implies that each country shall make its choices and decisions freely and shall have the means necessary to keep control of its freedom of decision." According to the Ingenieur General Cauchie, this freedom of decision requires direct control of the source of its military supplies. He cites the US embargo on arms shipments to Turkey as evidence that France, indeed Europe, "...cannot afford, even in the hope of a possible better utilization of resources, to jeopardize

[1]This speech also appears in the proceedings of the WEU meeting [35] with a slightly different translation. Other references to this speech will be to the later printed version [9].

its armament industry without taking the risk of getting disarmed some day."[1] [13, p. 22]

The UK and FRG tend not to stress this issue; they may be less concerned than the French or perhaps they are less frank. Sir Clifford Cornford, Chief of Defense Procurement, Ministry of Defense (UK) writes that [14, p. 46]: "It is important that Europe does not, over the years, progressively standardise on US equipment. This will not help Europe's self-respect; will reduce its engagement in its own defense." This statement makes a slightly different point: a country that buys its weapons abroad will lack self-respect and will not feel that it is participating in its own defense program. Paying for weapons is not like making them yourself.

Another British official, the Director of Munitions in the British Embassy in Washington, thought it important to stress--to an American audience--the potential, if not the desire, of the UK to supply a full line of weapons for itself [15, p. 23]: "It is important that the reader should be aware, however, that the United Kingdom still retains the ability to design, develop and manufacture the whole range of modern defence equipment, although for resource and standardisation reasons, some areas have in the past been and will in future be deliberately abandoned, at least for an equipment generation."

The issue of independence is a political one. Writers in Europe in the late 1960s were citing two threats to the

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[1]This view is consistent with French foreign policy pronouncements since US military aid to France was terminated in the mid-1950s. See for example [10, pp. 355-356] and [11, pp. 69-71, and 151 ff.]. Both books refer, for the most part, to nuclear weapons but it is clear in the context of passages cited by both authors that the perceived relationship of independence and control of arms production includes conventional arms. The unspoken use of conventional arms to pursue an independent foreign policy may be to supply them to non-European countries, see [11, pp. 166-169]. For the story of France's difficulty when she depended entirely on US and British arms, see the official US Army history of rearming the French in World War II [12].

political and economic independence of Western Europe--one from the East and one from the West. They had by no means settled on which was the most severe; some leaned toward the US as the greater threat. One British author sees the West Europeans in the same relationship to the US as the East Europeans must feel towards the Soviet Union [16, p. 260]: "East European countries harbour towards Russia many of the anxieties which West Europeans sense towards the United States. Both feel overshadowed by a giant partner." The French, more than the British, have viewed the threat of US hegemony with alarm. The thesis of Servan-Schreiber's well-known *The American Challenge* [17] was that not only Europe, but the world might be submerged by American economic power.[1]

The buildup of Soviet conventional forces in Europe has increased anxieties about Soviet intentions, while other factors--such as the falling value of the dollar--have reduced European anxiety about the US. Nevertheless, the association of development and production of a full range of arms with national sovereignty and European independence is clear. This fact must not be lost sight of in the pursuit of a common arms policy that could lead, under some circumstances, to increased US dominance of NATO arms development.

B. ECONOMICS OF COOPERATION

France and the UK stress that costs and budgets drive arms cooperation within Europe; the FRG policy statements emphasize other advantages to cooperation. All three countries see independent development of advanced technology weapons as becoming too expensive. Thus, cooperative European development

[1]This book was widely read in Europe and had an immense impact. Of course, his view was no more extreme than General DeGaulle's view that the US and the USSR were threatening the establishment "of a double hegemony." For an excellent and well-documented presentation of DeGaulle's view on the threat of US hegemony see Kolodzeij's review of French Foreign Policy under the Fifth Republic cited earlier [11].

is seen as a way of affording participation in such advanced technology projects. These projects are admittedly more expensive than those undertaken by single countries but less expensive than several countries undertaking independent projects to develop similar weapons.

One straightforward statement that the great expense of modern weapons is driving cooperation was made by Mr. Victor Macklen, Deputy Chief Scientific Advisor of the UK Ministry of Defense, before an American audience at a symposium of the American Defense Preparedness Association [19, p. 9]: "The high development costs and small production runs of modern weapons systems have led my country into a policy of equipment collaboration and purchase of fairly long standing, and we found other countries in Europe who have also been affected the same way."

Ingenieur General Cauchie, speaking for the French government to the Assembly of the Western European Union, sees budgetary constraints combined with weapons complexity as the leading force for arms cooperation in Europe [32, p. 30]. At first "...budgetary constraints justified co-operation only for major programmes such as the MRCA, Roland or Jaguar in which national budgets hesitated to take individual action.

"But the growing complexity of arms systems (and correlatively their cost) is now upsetting all the conventional data of defence budgets and is delaying or slowing down many programmes for lack of the ability to devote the necessary annual sums; this phenomenon is even evident in the United States which would have been unimaginable ten or five years ago. The benefits of economy of scale resulting from long production runs, coupled with cost-sharing at the research stage, even if costs are all the greater in a joint programme, would alone be enough to explain the recent generalisation of co-operation."

Hans Eberhard, the FRG armaments Director, writing for an American audience [20, p. 19], stresses that collaboration will

increase the effectiveness of the Alliance but does not neglect economic and technical benefits: "Enhanced armaments collaboration promises enhanced effectiveness of the Alliance.... However, it should be pointed out that collaboration may mean an increase in technical know-how for trade and industry. It may also help overcome dependence on an industrially dominant partner, or may afford the chance of increasing the rate of export, or be conducive to alleviating the situation on the labor market--a grave concern shared by all the members to the Alliance.

"If all these factors play a role in armaments collaboration, it cannot be confined to efforts in the technical sphere. It must be undergirded by resolved efforts in the political sphere."

The FRG tends to stress other values of cooperation rather than cost saving. Its spokesmen emphasize military effectiveness and what they see as the side benefits for trade and industry. The difference is that, since World War II, the FRG has not been allowed an independent arms industry or even an independent foreign policy. Politically they see themselves as having no choice but to increase cooperation and to keep their interdependence with their Allies. France and the UK, on the other hand, would like to have an independent arms industry--if only they could afford it; they see themselves driven to cooperation by tight budgets and more complex expensive weapons. Cooperation, and particularly specialization, are not seen by these two countries as the natural state of affairs that one would expect in arms development and production.

C. TRANSATLANTIC DIALOGUE

The European powers perceive US intrusion in that the US sells too much to Europe, thus weakening the European alliance defense industries. In fact, as we showed in Chapter II, the problem is not that the US sells too much to all of Europe but

rather that the US sells too much to the smaller European countries, thus depriving the industries of France, FRG, and UK of major markets. Nevertheless, the statements are couched in terms of US sales to "Europe" rather than to certain countries in Europe.

The FRG is least concerned about US intrusion in the European market. The following quotation from *International Defense Review* is based on their interview with FRG Secretary of State for Defense, Dr. Karl Schnell [22, p. 36]: "The German Ministry of Defense is convinced that collaboration should not only be restricted to Europe. It is, therefore, essential that a start is made on transatlantic talks as proposed by President Carter. In Bonn it is felt that productive collaboration is only possible if both sides, the USA and Europe, create a more balanced flow of defense material in both directions across the Atlantic than has been the case in the past. Schnell has referred to President Carter's program as one of the most significant US moves on NATO since Kennedy's offer of an equal partnership between the USA and Europe."

He goes on in the interview to discuss the Independent European Program Group (IEPG) and its transatlantic dialogue with the USA. According to the International Defense Review article: "While the transatlantic dialogue will not, Schnell says, exclude bilateral agreements between individual European countries and the USA, such agreements should not weaken the joint European position."

Hans Eberhard, in the article cited earlier [20, p. 19], emphasizes the importance of building up *European* cooperation to the point where Europe would be an equal in any transatlantic partnership: "Political discussions have revealed that industrial partnership with a powerful and completely self-reliant country, such as the United States, is and can only be maintained by a community of countries, which, on the basis of its joint capacities, will then be accepted as partner."

Thus, from the German point of view, the US initiative for a transatlantic dialogue should result in a European arms industry comparable to the US industry and in more European sales to the US. Moreover, there should be a decrease in US initiatives to sell or coproduce with one or a few European countries, such as the US sale of the F-16 fighter aircraft to Belgium, Denmark, the Netherlands, and Norway.

If there has been any ambiguity about the French position of the transatlantic cooperation, General Cauchie says [13, p. 25] that although the French "...are very grateful to Dr. Perry for his enthusiasm, his clear views, and personal engagement...," enhancement of Europe's defense nevertheless "...can only be achieved by reinforcement of the technological and industrial defense capabilities of European countries."

The French concern about US interference in European markets and perhaps more, their resentment against their neighbors for buying US equipment was expressed by Pierre Mayer, Inspecteur General des Finances before the Western European Union [30, p. 53]: "...an end must be put once and for all to the alibi and the deception of claiming that since the purchases of armaments in Europe are by national decision and not European, everyone is free to decide at will for the procurement of American equipment. In fact, a deliberate policy of preference for European armaments is indispensible if European industry is to avoid being submerged. Indispensible too if co-operation with the United States is to be built on more meaningful foundations."

As pointed out in the previous chapter, France does not buy non-French arms although it does engage in limited cooperative development and production. Thus, the prescribed policy is for France to buy French and for the other European countries--at least those without a highly developed arms industry--also to buy French, particularly in preference to the US. It is only this path that will lead to "co-operation with the United States."

The major example of US use of a European designed weapon system--the US purchase of a license to build the French-German Roland air defense weapon--appears not to be appreciated by either country. They would have much preferred direct procurement of the system, rather than the license. General Cauchie [35, p. 22] notes that "...the United States, with a potential market of $1,500 million, had a splendid opportunity of making a gesture in favour of just such a two-way street, instead of purchasing strictly nothing but the license."[1] Similarly, Carl Damm--a prominent member of the West German parliament, active in NATO arms collaboration--has said [23, p. 25]: "License-production like the 'Roland' are not purchases and their license fees are insignificantly small." He does note, however, that the system could be the beginning of a two-way street in arms procurement.

As suggested earlier, the key--from the French point of view--to arms cooperation is that the French arms industry be independent of the US. The British and German views seem not far from this, except that--quite naturally--neither country appears to view the French as being as central to the process. All three stress the importance of Europe as an equal partner to the US, with a balanced (read roughly equal) flow of equipment and with access to advanced US technology.

To keep the viability of their arms industries, the French and British--and increasingly the Germans--find that greater access to the rest of the NATO market is essential, and so is the almost unrestricted sale of arms to the developing countries. It is to this issue that we now turn.

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[1]If the $1,500 million figure is correct, and assuming half the sales would go to France, a Roland sale to the US would have meant that the US would have bought about twice as much in arms from France as France has bought from the US since World War II. (France received over $4 billion in military aid from the US in the 1950s.)

D. NON-NATO ARMS SALES

Quite possibly the major stumbling block to transatlantic arms production is the question of selling those arms to the developing countries of the world. The political and economic importance of such sales must be a major consideration in any program to increase arms cooperation.

The *French White Paper on National Defense: 1972* [29, p. 51], contains the following:

> The complaint is often made in France that our industrial armaments policy has led to a significant development of our export of military weapons systems. This recognition of the quality of our armaments is also seen as a contribution to world tension.
>
> It should be pointed out that our exports of military materiel have a twofold basis, both political and economic.
>
> Political basis: It is difficult for us not to respond to the requests of certain countries which are anxious about their defense and which wish to guarantee it freely without joining sides with one of the major powers of the two blocs. Were we not to respond to these requests, there would be an accentuation of the hegemony of the superpowers and it would also mean renouncing all the moderating influences attached to our position as an exporter, such as for instance refusing to sell arms which because of the circumstances might aid aggression. Many other countries do not have such reserve.
>
> Economic basis: We have already discussed the advantages of exporting--a better distribution of the expenses involved, increase in the quantities produced, therefore amortizing fixed costs over large series, and the opportunity for our firms to test their competitiveness on the international market. It should also be noted that exporting materiel to highly industrialized countries, themselves having an armaments industry, often involves compensatory factors, such as providing us with materiel which we do not ourselves produce or more frequently with parts of the finished product if it is manufactured cooperatively.

In 1974 the French Defense Minister, Robert Galley, pointed out that the French five-year plan for 1975-1980 could

support conventional arms development programs only with large export sales [cited in 21, p. 40]. Thus, French plans for the last few years were predicated on strong arms export sales, which have, in fact, been realized.

More recently, Ingenieur General Cauchie emphasized--again to an American audience--European dependence on arms exports as well as the unfairness and inconsistency of US policy [13, pp. 22-23]:

> ...for Europe, the European defense market is much too small to ensure by itself the survival of our technology, of our development centers, and of our production capabilities in Europe. The very principle of sovereignty and of security in Europe obliges [us] therefore to participate modestly in outside markets. [This participation is] not significant in comparison with the total arms transfer in the world, it is about 10 percent for all Europe compared to nearly 50 percent for the US sales [1]. This European participation is vital for the survival of Europe and represents also a minimum critical level. Therefore, a reduction of European transfers to the Third World would have to be compensated for Europe by an increase of its sales to the United States or by a reduction of the European buys from the United States....Otherwise, the European defense capabilities could be endangered and consequently the security in Europe.
>
> My next point will be arms transfers and RSI. Here [there] appears as far as [Europeans are concerned] a contradiction between two important present directives of the US government. On one side the efforts the US requests from the European[s] in the field of arms transfer which would entail a drop of our already low level of such transfer[s], a drop which could only be compensated, as I said earlier, by [a] corresponding opening to Europe of the US market. And on the other side of the contradiction we find the effort the US also requests of the European in the spirit of RSI. [An] effort which, like the NATO-wide defense market, would

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[1]The figure for European and US sales worldwide are ACDA figures, which are p. .bably low by a factor of two. General Cauchie should be aware of this fact since the French government and industry are the sources of the higher figures [24,25, and 26]. For example, in 1977 French military equipment sales--not deliveries--amounted to about $6 billion, or about half of the US level [26, p. 499] (author's footnote).

certainly lead [,] on the contrary [,] to an increase [in] the proportion of US weapon systems in Europe.

Although spokesmen of neither the UK nor the FRG emphasize non-NATO sales in general policy statements, there is some evidence they consider these sales to be important. The British, in particular, are heavily dependent on arms transfers, with about one-third of its output sold abroad [27, p. 4]. One defense official, Sir Ronald Ellis, Head of the Defense Sales Organization, gives the UK position of defense sales as "...a respect for the right of other countries, as sovereign states, to protect their independence and to exercise their right of self-defence" [27, p. 3]. According to Sir Ronald, the benefits include employment, balance of payments, and spin-offs from advanced technology: the UK does well by doing good.

But the UK does not "meet all the requirements willy-nilly." Political and military implications are examined before a sale is approved [27, p. 3]. Nevertheless, overseas sales are considered in equipment planning by the Services [27, p. 6]: "...when any new project proposed for the U.K. Services is under consideration, special regard is paid to its export potential.... The DSO [Defense Sales Organization] is consulted at all stages of a development programme and it sees that export considerations are not overlooked."

In summary, the French and British consider foreign sales to be an important instrument of foreign and military policy, and to be important economically. It matters little whether the original reason was to give others the right of self defense, to buy political influence abroad, to barter for oil, or to make arms less expensive for their own forces.[1]

[1]It has been suggested that the UK campaign to increase sales was launched in reaction to the vigorous US sales campaign carried out at Secretary McNamara's behest [28, p. 105], which was thought likely to eat into UK sales if it went unanswered.

E. THE IMPORTANCE OF WEAPONS STANDARDIZATION

The Europeans are notably unenthusiastic about standardized weapons, probably because they assume that the standardization would be around US weapons. At the minimum there would be standardization based on US decisions, since in most areas the US is the major consumer.

The British view, as given to an American audience by Victor Macklen [19, p. 11], is as follows: "Turning to rationalization and standardization, I'm going to have to say quite bluntly it is totally unrealistic to expect all NATO forces to have identical weapon systems. This may happen in some cases, but as a generality the proposition is absurd. While it is certainly true that if all the allied forces used American-designed equipment, the effectiveness of the allied forces might well be higher in purely military terms. The economic balancing factor in that equation is just missing and the strength of the alliance might be severely damaged if we try to go through such a process in the absence of an absolute threat of immediate war.

"Thus, I have the feeling that interoperability is generally speaking a more pervasive factor than full standardization. And in the end most of the military operational arguments boil down to a need for interoperability, particularly in areas like air defense, communications, data transmission, fuel, and perhaps ammunition. And here the term rationalization may show its head, for we all ought to have the same reserves of ammunition and fuel even if they're different between the different nations. And all these reserves ought to be based on the same assumptions of [rates] of consumption. There is no point in one part of our alliance running out of ammunition in three days while another has 30 days' supply."

The German position, as advanced by Hans Eberhard, favors some sort of common planning but goes on to say [18, p. 16]:

"But do we need really standardization in the field of equipment. We know, of course, that the term standardization implies varying degrees of intensity; namely, as you already heard, comparability, interoperability, and identity. These are not mere words. They are indicative of the collaborative possibilities to the parties, to the alliance, and the industries. And even at this juncture we can say this: No identity [is necessary]... where [the weapons] complement each other and where tactical considerations make identity unnecessary but perhaps financial considerations even make it undesirable, as Mr. Macklen pointed out just before.

"Identity or commonality of equipment will be expedient and desirable where time and money can be saved on development and production and where operational costs can be kept down to below those of two or three supply lines. Whether identity is an advantage from the military point of view is a point you can argue for or against. It can be vitally necessary in the case of multinational forces in close cooperation. It certainly is vitally necessary in national formations of any size." So identical equipment should be acquired where it can save money (which is not always the case) and even the military case against identical equipment is arguable.

The French position on weapons standardization is particularly negative. According to Ingenieur General Cauchie [35, pp. 22-23], standardization not only makes it easier for the enemy but it also leads to producer specialization (which will infringe on sovereignty), impacts badly on labor markets and forces consumer countries to deal with producer monopolies. On the other hand, interoperability has "nothing but advantages."

Thus, the concept of standardization--that is, furnishing the various countries of the Alliance with identical weapons--is not looked upon with favor by our European Allies, even in

principle. This suggests that working out an agreement whose major aim is standardization is likely to be most difficult.

F. IMPLICATIONS

A major thrust of European arms cooperation policy is to maintain and strengthen European arms development and production capability. There is some difference in emphasis but only the FRG stresses the necessity to increase efficiency in order to offset the Soviet buildup of the last decade. As we saw in the last chapter, since France and the UK buy little from the US, and since US sales to the FRG seem likely to decrease now that the offset agreement no longer exists, a balancing of US-European arms trade can come only at the expense of US sales to the other European countries. The US is being asked to withdraw from the European market to give France, the FRG, and the UK greater access to the other European buyers, namely Belgium, Denmark, Italy, the Netherlands, and Norway; that is, those countries that can afford to pay for arms.

Even if we could ignore the difference in scale between the US and Europe as being unimportant, there are other problems in arms cooperation: (1) the interests of the major European producers conflict with each other; and (2) the interests of the major European producers conflict with the medium-sized European producers and consumers. On the last point--there is no reason to believe that it is in the interest of the Alliance or of the smaller countries for the US to abandon the NATO European market to the major European producers.

In addition to those conflicts, we have problems of scale. The arms industry of the major European producers--taken together--is only about half the size of the US industry. Even adding other European producers raises the proportion only a little, assuming they would be let into the club with the three biggest producers. This imbalance makes agreements that pretend

equality very difficult to achieve. The US--with two-thirds or more of the buying power and production capability--is bound to dominate. The major European producers do not offer, among themselves, a *complete* line of weapons equal in variety and depth to the US offering and could do so only with great difficulty and significant increases in defense spending. What is more, their geography, overseas interests, and strategic approaches have led the major European producers to place differing emphasis on the various defense missions among themselves and between themselves and the US. It is to these issues that we turn--in the context of tactical missiles--in the following three chapters.

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Chapter IV

NATO TACTICAL MISSILES: HISTORY

A. TACTICAL MISSILES: TERMS OF REFERENCE

In this chapter we will look at the history of the development of tactical missiles among the four major NATO powers as one step in evaluating the possibilities of future cooperative efforts. To keep the study in bounds, we have excluded strategic weapons from consideration, as well as nuclear-capable tactical weapons. An exception is made, however, for the early US surface-to-air missiles which preceded today's weapons but were designed initially with nuclear warheads to defend against nuclear-weapon-carrying manned bombers.[1]

A survey of the types of tactical missiles which the major NATO powers developed and fielded over the years reveals a pattern of mission interest and emphasis that should be considered in negotiating viable cooperative development and production agreements. In the more than 30 years of modern tactical missile development, we can observe national weapons development

[1]Along with the medium range and intercontinental ballistic missiles, such as Thor, Atlas, Titan, Minuteman, and Polaris, we have chosen to exclude such weapons as Regulus I and II, which were nuclear-armed, sea-launched cruise missiles, and Matador and Mace which were tactical nuclear land-based cruise missiles. The appearance of similar cruise missile weapons in the late 1970s, such as Tomahawk, does not represent a development of the earlier models but an application of new technologies to the same problem. Tomahawk can be used tactically with a conventional warhead—although it is an expensive solution. Regulus and Matador/Mace lacked the accuracy required for conventional use. As an historical aside, the early air-to-air missiles, such as Falcon, were designed to carry nuclear warheads for use against mass formations of bombers.

as not simply a matter of fixed national style, but as responding to world political events involving tactical lessons and changing national strategies. There is also the thrust of technological development itself, which can create potentialities that lead to new tactics and strategies.

Before we sketch the history of tactical missile development in NATO, we will specify the terminology which we will be using. Standard abbreviations are changing in this field, but in Table 12 we show the generic classifications, the type of launch platforms, the targets and two of the commonly used abbreviation systems. For convenience we have used the term "tactical missiles" to mean tactical guided *missiles* and tactical guided *weapons*, which permits us to include some *unpowered* (i.e., gun-launched, free-fall) but terminally guided weapons such as the Paveway guided bombs (GB).

B. TACTICAL MISSILES: A BRIEF HISTORY

One of the most expeditious ways to sketch the history of tactical guided weapon development is to list some of the major milestones in the field by era and country. Table 13 is such a chronology, characterized by the events of each decade which set the tone or changed the direction of armament emphasis. The full set of variations of such long-lived US systems as the Sidewinder (AIM-9), Sparrow (AIM-7), and Falcon (AIM-4) is not shown; the point being to mention significant new departures in terms of technology or mission capability. The years shown are the approximate dates at which development might be said to be substantially "complete" for a particular model of the weapon. In most US cases it is the date of initial operational capability (IOC)--that time when an operational unit is completely equipped with the weapon and operationally ready. In the European cases the date varies from that of initiation of series production to announced dates of development completion

Table 12. TACTICAL MISSILE TYPES AND ABBREVIATIONS

Missile Type	Launch Platform	Target	Standard English Abbreviation	French Designation System
Surface-to-air (land)			SAM	n.a.
Man Portable	Man-held launcher	Aircraft	MANPAD	n.a.
Short-to-medium (altitude/range)	Towed or self-propelled vehicle	Aircraft	SHORAD	n.a.
High-to-medium (altitude)	Fixed or movable launcher	Aircraft	HIMAD	n.a.
Surface-to-air (sea)		(Naval)	SAM	n.a.
Short-range	Ship	Aircraft	SAM	n.a.
Medium-range	Ship	Aircraft	SAM	n.a.
Long-range	Ship	Aircraft	SAM	n.a.
Air-to-air			AAM	AA
Short-range	Aircraft	Aircraft	SRAAM	AA
Medium-range	Aircraft	Aircraft	MRAAM	AA
Long-range	Aircraft	Aircraft	LRAAM	AA
Anti-tank			ATGM(ATM)	SS
Man Portable	Ground or man-carried launcher	Armored vehicle fortification	ATGM(ATM)	SS
Heavy	Vehicle	Armored vehicle fortification	ATGM(ATM)	SS
Heliborne	Helicopter	Armored vehicle fortification	ATGM(ATM)	SS
Air-to-Surface			ASM	AS
Anti-radiation	Aircraft or helicopter	Radar or other emitter	ARM	AS
Other Powered	Aircraft or helicopter	Structures, vehicle, personnel, equipment	ASM	AS
Other Non-powered (glide bombs)	Aircraft	Structures, vehicles, ships	GB	n.a.
Surface-to-surface (not anti-tank)			SSM	SS
Land	Towed or self-propelled launcher	Structures, vehicles, personnel, equipment	SSM	
		Ships	ASSM	SM
Sea	Ship	Ship	ASSM	MM

[a]The official designation system of the Defense Department uses a three-letter/number system described in Reference [1]. The US missile designations from that reference are included as Appendix B. These abbreviations will be used occasionally in the text and frequently in tables to conserve space. The abbreviations change all too frequently. As an example, when the study was initiated, ATGM (anti-tank guided missile) was being replaced by ATM (anti tank missile). In the last few months the ATM designation has also been used to mean "anti-tactical missile" systems, i.e., missiles to defend against missiles.

Table 13. NATO TACTICAL MISSILES DEVELOPMENT PROGRAMS BY COUNTRY AND TIME PERIOD[a]

Period		Country			
Years	Characteristics	US	France	UK	Germany
1939-45	World War II	VB 1944 ASM LARK SAM[b] JB SLCM[b]			V-1 1944 SLCM V-2 1944 SSM Fx 1400 1944 ASM Hs 293-296 1944 ASM "Wasserfall" SAM[b] "Rheintochter" SAM[b] Hs 117 "Schmetterling" SAM[b] "Enzian" SAM[b] X-4 AAM[b] Hs 298 AAM[b] X-7 ATGM[b]
1945-54	Era of nuclear bomber Colonial wars Korean war	Nike Ajax 1953 SAM Terrier 1953 SAM Hawk 1954 SAM (C)[c]			
1955-64	Nuclear proliferation Long-range bombers and medium range missiles give way to ICBM's at end of erra Massive retaliation gives way to mutual deterrence and brush fire wars	Falcon 1955 AAM Sidewinder 1956 AAM Sparrow 1956 AAM (C) Tartar 1956 SAM Bomarc 1957 SAM Talos 1958 SAM Nike Hercules 1958 SAM (C) Bullpup A 1959 ASM Nike Zeus 1960 SAM Bomarc B 1961 SAM Redeye 1964 SAM	AS.11 1955 ASM SS.10 1955 ATGM AA.20 1956 AAM SS.11 1956 ATGM R 511 1957 AAM Entac 1957 ATGM Parca 1958 SAM R.422 1958 SAM AS.20 1959 ASM AS.30 1960 ASM Masurca 1960 SAM R 530 1963 AAM	Bloodhound 1957 SAM Firestreak 1958 AAM Thunderbird 1959 SAM Seaslug 1962 SAM Seacat 1962 SAM Vigilant 1963 ATGM Red Top 1964 AAM	Cobra 1960 ATGM
1965-74	Nuclear deterrence Vietnam war Middle East wars India - Pakistan war Proliferation of new national states ABM agreement	ABM efforts accelerated 1965 Shrike 1966 ARM Walleye 1966 GB Chaparral 1966 SAM Shillelagh 1967 ATGM Sea Sparrow 1967 SAM (C) Maverick 1968 ASM Paveway 1968 GB Phoenix 1969 ASM Hobos 1969 GB Tow 1970 ATGM Dragon 1973 ATGM	SS.12M 1966 SSM AS.37 1968 ARM (J)[c] Crotale 1968 SAM Exocet 1972 SSM Milan 1972 ATGM (J) Harpon 1973 ASM	Rapier 1967 SAM Blowpipe 1968 SAM AJ.168 1968 ASM (J) Swingfire 1969 ATGM Sea Dart 1973 SAM/SSM	Mamba 1972 ATGM Milan 1972 ATGM (J)
1975 - date	US non-intervention in third world SALT negotiations NATO emphasis by US Third world armament continues	Safeguard 1975 ABM[d] Stinger 1978 ATGM AIM-9L 1978 AAM (C) Harpoon 1978 SSM Harm 1980 ARM Improved Hawk 1980 SAM Patriot 1980 SAM Copperhead 1980 SSM Tomahawk 1981 SLCM/ALCM[e] AGM86 1981 GLCM/ALCM[e] Laser Maverick 1981 ASM AIM-7M 1981 AAM Hellfire 1981 ASM/ATGM	Otomat 1975 SSM (J) R 550 1975 AAM Exocet 1977 ASM Roland I 1976 SAM (J) Hot 1977 ATGM (J) Super 530 1980 AAM AS.30L 198 ASM	Sea Wolf 1977 SAM Skyflash 1978 AAM Sea Skua 1980 ASM	Kormoran 1977 ASM Hot 1977 ATGM Roland II 1980 SAM (J)

[a]Includes only most significant variations of families. See Appendix A for explanation of relationship among various tables and appendices listing tactical missile programs.

[b]Development only.

[c]Symbol (C) indicates licensed production or coproduction in NATO. (J) indicates product of joint development program.

[d]Deactivated in year deployed.

[e]SLCM = submarine Cor surface launched cruise missiles. Competitive in tactical and strategic ALCM = air launched. GLCM = ground launched roles. Only one may be procured.

Sources: References [2-14].

(which can come well after series production has begun and even after operational deployment in unit service).[1]

While the German missile program is best remembered for the first modern long-range ballistic rocket (V-2) and the first operational cruise missile (V-1 "buzz bomb") because they were used to bombard European cities, the chronology reminds us they also had successful air-to-surface missiles which actually sank warships and demolished bridges. By the end of the war, the Germans had one or more surface-to-air, air-to-air, and anti-tank weapons in advanced stages of development, and had fired many of them in tests. Almost all of the fundamental problems a guided weapon designer must solve in target acquisition were addressed--tracking; initial, mid-course, and terminal guidance; directional control and stability; fuzing and warheads. Wire command guidance, radar beam riding and terminal homing, infra-red tracking and homing, the use of television for guidance and electro-optical devices for homing were all employed in operational platforms or test weapons [2,15,16,17, and 18].

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[1]Since the late 1960s and the formalization of the DSARC (Defense Systems Acquisition Review Committee) system--at which key decisions on continuation of a development program are marked by convening a review committee--the significant dates in US programs are fairly easy to ascertain. Where "fly before buy" procedures obtain, the "fly-off" (or shoot-off) and subsequent choice between competing systems provides a significant date. Either this point or the decision to proceed with production, DSARC III, would seem to be the end of the development process. However, before a weapon is deployed operationally, there will be production prototypes for testing by the producer, followed by design changes which yield first production series units for user "test and evaluation" with further modification to weapons on the production line and backfitting of previously produced ones. Thus, the US IOC is a fairly late date in the development process. European practice is seemingly less formalized, or less is disclosed publicly about it. From what can be gleaned from the trade press, the Europeans appear to issue weapons widely to operational units earlier in the process of test and evaluation. Since inventories of weapons are not scattered over a wide area, as is the case in the US, backfitting and modification may not pose the problem it would in the US system. In sum, our procedure may indicate an earlier completion date for European development than if US practices were followed.

The US produced an operational guided weapon, the VB series of guided bombs, which began as "Azon" (*Az*imuth *on*ly), a freefall bomb in which the azimuth direction of the fall could be changed but not the range. The other two efforts shown in the table were abandoned when the war ended [3]. Whatever the detailed reasons for the disparity in interest in guided weapons between the Allies and the Axis, the overwhelming Allied superiority in the size of conventional forces in Europe made exotic weapons as superfluous to the Allies as they were essential to the Axis.

After the Allied victory, many of the lines of German development in guided weapons were not pursued in weapons development programs.[1] But perhaps more important, interest turned to nuclear weapons; one did not require much accuracy to destroy a target. Thus, tactical missile development was limited to air defense, largely against attack by nuclear weapons carriers. Moreover, the demands were quite high--not even a single attacker could be allowed to penetrate over a wide area.

In the decade after World War II, the principal line of the German beginnings that was followed up by the US (with some of the same German engineers and scientists) was in surface-to-air missiles. It is still difficult to appreciate that the only guided weapons fielded in a period that included the Korean war were three US surface-to-air systems. The Nike Ajax was a fixed-site weapon for defending centers of population or industry against attack by the high flying bombers which would be carrying nuclear bombs. It has been described by one source as a direct descendent of "Wasserfall" [17]. Hawk, which still is widely deployed around the world, provided an early capability to deal with any low fliers that might underrun Nike Ajax's

[1]A fairly complete knowledge of the German developments was obtained by the US, along with many of the technicians. Reference [2] is a contemporary (once classified) description of the data and equipment.

high altitude watch, since even one penetration through the air defense was too many if it carried nuclear weapons. Hawk also provided a movable system to be deployed in the field in defense of expeditionary forces at airfields and beachheads, although that was probably an incidental capability. The Navy Terrier system, an outcome of the Johns Hopkins Applied Physics Laboratory Bumble Bee program of World War II, provided the radar-directed missiles, which would make it possible for the Navy's carriers--with their armored flight decks--to operate against landbased air. The much improved successors are today's "Standard" missiles.

In the 1955-64 decade, tactical missiles proliferated in France and the UK, as well as in the US. The Soviets, with a growing nuclear arsenal of their own, developed long-range bombers, some of them armed with nuclear tipped cruise missiles with stand-off capabilities. In the US, this led to efforts to increase the distance from the cities or the fleet at which the bombers or missiles could be intercepted. Bomarc, a *cruise* supersonic anti-aircraft missile, was one such weapon actually fielded and is still serving today as a high-speed target drone for development work. Nike Hercules, still in European service, extended the range and altitude capability of the earlier Ajax missile. At the same time, three air-to-air missiles--Falcon, Sidewinder and Sparrow--were produced for Air Force and Navy aircraft to use in intercepting the bombers as far out as possible. The lone weapon that seems to reflect the Korean War experience is Bullpup--a weapon to destroy targets such as the caves and bunkers that thwarted US air interdiction efforts in 1952.

On the other side of the Atlantic, the UK scientists were developing similar weapons to deal with a similar problem. The threat to the British Isles was principally a threat from the air. The urgency of the effort is attested to by the fact that

two separate systems, Bloodhound and Thunderbird, were completed at about the same time and had almost identical performance characteristics [3]. The French also developed two high-altitude SAMs but their concentration (more apparent when production data for the period are examined) was on anti-tank guided missiles.[1] First, they developed man-portable wire guided weapons perfecting the German World War II beginning in the SS.11 and Entac; then bigger weapons for vehicle carriage and air launch such as the SS.12 and AS.12. Two of the French air-to-air weapons of this period, AA.20 and R.511, were technically behind the US counterparts, but appear to have been developed to provide French weapons for increasingly sophisticated French-built fighters of the period. The French sea-based SAM, Masurca, has not been followed by any significant further development of sea-based air defense weapons. The lone West German weapon of its period, Cobra, was a simple Entac-type weapon which was exported in large numbers to Latin American countries [3,5, and 11].

At the end of the period, the strategic burden had shifted from bombers to ICBMs and submarine-launched ballistic missiles. In the surface-to-air field in the US, one can identify the beginning of a decade of US Army concentration on the problem of intercepting intercontinental ballistic missiles. The efforts built on the Nike technology. As the nuclear stand-off developed, US interest turned to counterinsurgency and tactics and weapons for dealing with brushfire wars.

The 1965 to 1974 period in the US begins with growing involvement in a ground campaign against guerrillas in South Vietnam and a Korean-style air interdiction campaign against North Vietnam. The deployment of many of the US air weapons reflected the urgencies of the latter campaign, although most

[1]Parca was developed and briefly deployed in one aircraft regiment before being replaced by Hawk in 1962. The R.422 was developed but not deployed [3, p. 146].

had begun development earlier. Shrike provided a means of coping with the SA-2 Guideline surface-to-air missiles defending North Vietnam's cities by knocking out the missile guidance radars. The guided bomb systems--Walleye, Paveway, and Hobos--provided a capability to hit land targets from a distance, as well as the accuracy needed both for pinpoint targets, such as bridges, and to meet the political requirement to minimize collateral damage to non-military structures and personnel. Maverick nominally provided an even greater stand-off capability. Shillelagh and Tow were the first US entries into the anti-tank guided missile field. Vietnam provided the combat testing to prove Tow an outstanding weapon while the Shillelagh went only to Europe. The development of Dragon as well as Tow represent a return to the NATO focus, giving US infantry forces a weapon for dealing with the Pact armor threat. Wire-guided infantry-deployed weapons had gone through two generations in European NATO forces in the preceding decade. With the Chaparral system, which was described--when it first appeared--as a five-year expedient pending development of the NATO weapon, the Army returned to providing a mobile air defense weapon for maneuver forces; a capability that only the relatively ineffective Redeye shoulder-launched IR missile had provided. Chaparral uses a modified Sidewinder AIM-9B missile and an existing tracked vehicle chassis.

The Navy in this period fielded only two new tactical missile systems in Sea Sparrow and Phoenix. The first, like Chaparral, used a modified air-to-air missile, the Sparrow, to create a short-range air defense system that has been fitted to US and NATO naval units as large as aircraft carriers and as small as patrol boats. Phoenix, coupled with the F-14 aircraft, provides the fleet with long-range interception capability to be used against both cruise-missile-carrying bombers and the cruise missiles themselves.

The European pace of development seems to have slowed in the 1970s, with a growing emphasis on cooperative development

and production. The French introduced two surface-to-surface anti-shipping missiles in the SS12M (M for *mer*) and the Exocet (which was to have not only sea and land surface-to-surface but also air-launched land and anti-ship versions in later years). With the UK, the French developed Martel, which is an air-launched weapon with electro-optical homing and anti-radar versions. The French used only the anti-radiation version, which they produced as AS.37. The British concentration is on the electro-optical version as AJ168, which equips British sea patrol aircraft. Both the British and the French produced short-to-medium range air defense weapons; Rapier for the British and Crotale (financed heavily by South Africa) for the French. Both are mobile, designed to accompany field forces. During the same period, the French and Germans cooperated in developing the Milan third-generation, man-portable anti-tank weapon and began on Roland--a mechanized surface-to-air missile--and Hot--a medium range anti-tank missile mounted on land vehicles and helicopters. Codevelopment and production was handled through Euromissile, a consortium--with minimal management responsibilities--created for the purpose of marketing the missiles. The British developed Blowpipe, an optically-tracked, portable surface-to-air missile, and Swingfire, their own mechanized anti-tank system.

Since 1975, the US has produced the latest in a series of improvements of its basic air-to-air weapons families, Sparrow and Sidewinder. During the 1960s, the original weapons underwent a series of improvements incorporating the new solid-state electronics in place of earlier tube technology in guidance and seekers, providing increased reliability and gaining space for improved warheads and motors in the original geometries. In the 1970s, the great advances in micro-processor technology permitted further performance improvements to be incorporated in AIM-9L and AIM-7F/M. Laser technology also becomes prominent in Copperhead, a laser-homing 155mm artillery projectile, and

Laser Maverick, and Hellfire, a helicopter-launched anti-tank missile. The range of possibilities opened up by these and other technical advances applicable to missile design appears to promise even more new systems in the 1985 to 1990 period [19,20].

What the US will choose to emphasize in the future is not clear from the record since 1975. Indeed, the US appears to be covering the full range of weapons: a new high-to-medium altitude weapon--Patriot; the Navy's first surface-to-surface missile--Harpoon;[1] a mobile al -weather short-range air defense system--Roland;[2] an effective man-portable missile--Stinger; and the use of laser designators by front-line troops to bring down Maverick and Copperhead missiles on enemy tanks. Thus, almost all tactical warfare areas are covered; those areas not currently covered will be by weapons now in advanced steps of development.

In contrast, the number of European development programs seems to have diminished, perhaps because of cooperation. Modest improvements in air-to-air missiles were made in Super 530 in France (R.530 successor, and Skyflash in Britain (a Sparrow successor). The areas coming to completion in the 1975 to 1980 period are the codevelopment of a European Tow-competitor in Hot by Euromissile, two versions of Roland, and two anti-shipping air-to-surface missiles in an improved Exocet and in German Kormoran. Work is continuing in laser-designated air-to-ground weapons for use with the French Atlis airborne laser target designator developed on contract by Martin-Marietta--a US firm. The French are producing Durandal, which is not exactly a missile but a rocket-powered parachute-retarded bomb for destroying airfield runways. The British, with the US, are codeveloping the JP233, also for destroying runways. The

[1]Harpoon, like Exocet, has an air launched version. It has, in addition, a submarine launched (submerged) version.

[2]Roland, although developed by the French and Germans, has required so much to "Americanize" it, that one might consider the US to be developing US Roland and thus to be covering even this weapon type.

absence of any programs for high-to-medium altitude missiles for area defense would seem to leave this field to the US and its Patriot air defense system.

We can sum up what this description of interest in tactical missiles reveals by showing the kinds of weapons developed as in Table 14. In the following section we look for a pattern to this development history.

Table 14. FOUR POWER TACTICAL MISSILE DEVELOPMENT EMPHASIS: 1945 TO 1978

(By IOC in Each Period)

Period	Types Emphasis by Country			
	US	France	UK	FRG
1945-54	HIMAD SAM	n.a.	n.a.	n.a.
1955-64	HIMAD SAM, AAM	HIMAD SAM, ATGM, AAM	HIMAD SAM, AAM	ATGM
1965-74	ASM, ATGM,	All except HIMAD SAM	SHORAD, ATGM	ATGM
1975 to date	All types[a]	All except HIMAD SAM	AAM	SHORAD SAM

[a]Except for a radar directed short range air defense system, e.g., Roland. But see footnote on previous page.

C. AN ALTERNATIVE CHARACTERIZATION OF TACTICAL MISSILE EMPHASIS

In this section we attempt to characterize national "styles" in tactical missile development. While what follows is speculative, it helps to understand how the development pattern is related to considerations of strategy and tactics.

As to the strategy question, consider the dominating NATO context for conventional conflict. The basic combat scenario is that of a combined Warsaw Pact land and air attack thrusting westward into Germany, with simultaneous counterforce sea and air attacks upon NATO forces and bases in the Mediterranean, in Scandinavia, and the North Atlantic. In developing weapons to contend with this scenario, one can imagine some extremes of

tactical doctrine and interest that provide a framework for characterizing different national approaches. One would be a passive strategy of defense that would attempt to defeat the attacking forces by killing them as they advance (a strategy of pure attrition emphasizing continuous fronts and exchanges of fire by engaged forces)--the Lanchesterian calculus, if one will. This would yield, for the defender with numerical inferiority (read NATO), weapons with high kill effectiveness and high survivability either through "hardness" or by outranging the opposition. At the other extreme is the strategy of o - coming one's numerical inferiority by disorganizing the enemy forces to such an extent that they are rendered ineffective. This is an active strategy of outmaneuvering the enemy so that his superior fire power is at the wrong place; or one of cutting his supply and communication lines so that his weapons are defeated by running out of fuel or ammunition; or his planes cannot operate because the airfields are destroyed, and so on [21,22]. What basic strategy is adopted will influence the weapons developed. The pre-World War II French approach that produced the Maginot line and developed tanks to be deployed as mobile "pillboxes" to support infantry in attrition battles is an historical case of an attrition strategy. The Germans, inferior in numbers and emphasizing mobility, speed, and disorganizing attacks, produced fast tanks and coordinated air attack weapons in the divebombers, one of whose functions was to spoil the efforts of an enemy to group forces for counterattack against mobile columns of breakthrough elements.

As for air forces, their function presumably is to help bring about a favorable resolution of the ground campaign by operating against enemy ground forces and/or preventing enemy air forces from interfering with friendly ground operations. At one extreme one can emphasize attriting enemy aircraft by defending one's own targets with fighter aircraft, missiles, and guns, or one can carry the battle to the enemy by destroying his

aircraft on ground, interdicting his airfields and supply lines via air attack. Historical examples of the two strategies are the UK tactics in the Battle of Britain as contrasted to the Israeli air force efforts in the 6-Day war. In the first case, one would expect emphasis on surface-to-air weapons with short-to-medium ranges and "dog-fighter" type aircraft. In the second, one would expect an emphasis upon fighter-attack aircraft and defense suppression weapons to aid them in carrying the attack to the enemy.

If we array the weapons developed by US and other NATO powers along a scale from "pure passive attrition" to "active disorganization," it might reflect the implicit strategies each country was pursuing--*insofar as this influenced or was reflected in weapons development choice.* To anticipate one of our findings, the distribution of weapons over an Alliance must reflect each member's financial capabilities so that, for instance, expensive weapons have tended to become *de facto* the prime responsibility of the US. Thus, the coincidence of weapons and strategy may also be a coincidence of fiscal necessity.

There is another measure of weapons development interest that, while not independent of strategy, reflects another dimension of choice--call it emphasis or style--which seems implicit in the development history. This measure reflects the degree to which the weapon is designed with attention to interaction among other weapons in a theater action involving many units and weapons, or is designed with a focus only upon the immediate engagement of weapon upon weapon--the action envisioned at the lowest unit of command. An example of this contrast from air warfare might be the French AM.38 Exocet weapon and the US Harm anti-radar missile. The first is a demolition weapon, suitable for any nonmobile target; the second is designed to put a radar out of action--presumably because some other weapon somewhere is attempting to accomplish some task which the enemy radar (missile, gun-laying, search, etc.)

threatens to interfere with. In air-to-air combat, a short-range "dogfight" missile such as the French R.550 Magic or the US AIM-9L focuses upon the immediate engagement of aircraft against aircraft, implying no more extensive scenario than a hostile encounter in the sky somewhere. On the other hand, although a single Phoenix missile is meant to intercept a single aircraft or cruise missile, the F-14/Phoenix system is designed to protect the carrier task force as a mobile force that must be protected over a theater-wide area from long distance attack. Moreover, the survival of the task force is thought to have theater-wide significance. Similarly, for surface-to-air missiles, Crotale is for 360 degrees defense of a mobile point target--say the spearhead of a tank column or a battalion headquarters. But a single battalion of Patriot, with its long range missiles, but less than 180 degrees radar coverage, implies an interlocking system of defenses to protect an area. In the NATO case, this is likely to be an entire theater of combat.

Focusing upon the named weapons misses a portion of the "weapon system" which helps to explain the classification choice for each named item, these being sometimes almost a "round of ammunition" for a more complex collection of devices and organizational elements. To some degree, more obviously with air-delivered weapons than others, we are characterizing the strategic style of the various nations. The US Air Force prefers broader concept.ons than direct support of front-line ground forces for its air-delivered weapons. To be assigned to missions of direct interest to and selection by ground force units, whether at the level of companies or divisions is to risk subordination of air forces, in fact, and in command, to ground force organizations. Its weapons interests, then, with some exceptions such as the A-10 aircraft and the Maverick weapon family, would tend to reflect theater-wide tactics partly independent of immediate concern of ground units. These Euro-

pean powers such as France, without high-seas fleets capable of mounting major operations (and being threatened by large air or naval forces), would not be expected to design weapons which depend for their effectiveness on fleet-wide synergisms. What one can show, perhaps, is that weapons *and* forces are consistent with general notions of how warfare will (ought to) be conducted. But one rationale affects another, and the high cost of some weapons can encourage adoption of the alternate strategy with an overlay of rationalization. Thus, in the case of nations such as Britain it may be also a question of what kinds of warfare a nation can afford to prepare for. Disentangling the complex interactions and rationales in a definitive way is probably not possible.

Nevertheless, one might posit two scales which could be used to classify weapons with indexes ranging from "Pure Attrition" to "Pure Disorganization" and from "One-on-One or Unit Combat" to "Theater Force versus Theater Force," with the various weapons ranged along the scale. Assigning any value beyond "more" or "less" would be an exercise in spurious precision. Thus, in Table 15, we have sorted the weapons mentioned earlier in Table 12 into four categories: Attrition/Unit; Attrition/Theater; Disorganizing/Unit; Disorganizing/Theater. Since current anti-tank weapons are almost all one-on-one, we have shown the count in Table 16 without anti-tank missiles.[1]

The tables show the NATO defensive emphasis strongly for all powers. The US interest in a larger scale of operations is reflected in the attrition weapons, which are primarily ground and sea based air-defense missiles, and in the disorganization weapons, which are the air-to-surface weapons developed for airfield and LOC interdiction in the manner of World War II, Korea, and Vietnam. The presence of French entries in all of the categories except "Attrition/Theater" could be interpreted to

[1]Weapons systems now in development such as Assault Breaker, the Wide Area Anti-tank Munitions (WAAM) being developed for utilization within the Assault Breaker system, and various other air, rocket, and gun-launched "buses" may change this picture for the future.

Table 15. TACTICAL MISSILES: SCALE/STRATEGY
(Number of Weapons Developed)

Combat Scale	Primary Emphasis: Attrition	Primary Emphasis: Disorganization
Unit	51: 17 US 20 France 11 UK 3 FRG	4: 2 US 2 France 0 UK 0 FRG
Theater	19: 15 US 0 France 3 UK 1 FRG	11: 9 US 2 France 0 UK 0 FRG

Source: Table 17.

Table 16. TACTICAL MISSILES: SCALE/STRATEGY
EXCLUDING ANTI-TANK WEAPONS
(Number of Weapons Developed)

Combat Scale	Primary Emphasis: Attrition	Primary Emphasis: Disorganization
Unit	35: 13 US 13 France 9 UK 1 FRG	4: 2 US 2 France 0 UK 0 FRG
Theater	19: 15 US 0 France 3 UK 1 FRG	11: 9 US 2 France 0 UK 0 FRG

Source: Table 17.

indicate some hitherto unappreciated similarity of French and US tactical doctrine. A more likely explanation is that it results from French competition with the US in the weapon export trade. What we can say, however, is that to have relied on any single country other than the US in the period would have been to court foreclosing at least one broad strategy option for want of suitable tactical missiles. In the case of France: no Theater/Attrition (read area SAM) weapons. In the case of the UK or FRG: no "Disorganization" (read aggressive tactics) weapons at either the unit or theater end of the scale would have been available.[1] The various weapons in each category are shown by name in Table 17.

No world fits neatly into such categories, but the scheme permits us to characterize a situation that the facts of later chapters tend to support. If we look at the most recently developed weapons for defending against air attack, we find the following: US Patriot, a long-range air defense missile, and AWACS (for early warning and command and control of theater air forces) to deal with mass raids. The absence of a follow-on to Thunderbird and Bloodhound and the interest in "dogfight" air-to-air missiles puts Britain nearer the French position, where ground-based air defense weapons are focused on defending field units, as with Roland; and air-to-air weapons are dogfight types. The US is also the only NATO partner with the full range of weapons (including missiles for suppression of defensive radar) needed to defend against air forces by penetrating and attacking them at their own bases. These missiles are also used for attacking oncoming ground forces before they reach the

[1]The West Germans have had to operate under special political constraints since World War II, foregoing the development of or even public expression of interest in weapons that might suggest aggressive potential. See for example, [23, p. 82], which stresses the "defensive" nature of German missiles. They are, however, going on, more recently, for air-delivered weapons (not missiles) STRABO and JUMBO which might be considered to be theater weapons by our definition.

Table 17. TACTICAL MISSILES BY SCALE/STRATEGY

Category	Country			
	US	France	UK	FRG
Attrition/Unit	Redeye Stinger Chaparral US Roland Sea Sparrow AIM-9B AIM-9D AIM-9G/H AIM-9L AIM-7C AIM-7D/E/F Dragon[a] Tow[a] Shillelagh[a] CLGP Harpoon Hellfire[a]	Crotale Roland I Parca R.422 Masurca AA.20 R.530 R.550 R.511 Super 530 SS.10[a] Entac[a] SS.11[a] SS.12[a] Milan[a] Hot[a] Harpoon[a] AS.11[a] Exocet Otomat	Blowpipe Rapier Tigercat Seacat Sea Slug Sea Dart Firestreak Red Top Vigilant[a] Swingfire[a] AJ.168	Roland II Cobra[a] Mamba[a]
Attrition/Theater	Bomarc Ajax Hercules Patriot Hawk Improved Hawk Terrier Tartar Standard 1 Standard 2 AIM-4A/E/F AIM-4B AIM-4C AIM-54A AIM-54C		Bloodhound I & II Thunderbird I & II Sea Skua	Kormoran
Disorganization/ Unit	Bullpup AGM-65C[b]	AS.20 AS.30		
Disorganization/ Theater	Shrike Harm AGM-65A/B[b] AGM-65D[b] Walleye I & II Condor[c] Hobos Paveway GBU-15	AS.37 AM.38		

[a]Anti-tank weapons (includes dual purpose).

[b]The placing of AGM-65C in the disorganization/unit category derives from the concept of operation, which envisions a ground-based (front line infantry unit) laser designator to effect homing. The A, B, and D versions can be used anywhere for any target.

[c]Cancelled after development completed.

Source: References [3-14]. Cooperative programs are listed under the primary developer. Does not include those weapons in Table 13 that were designed exclusively for nuclear warfare. Also includes more variations than Appendix D. See Appendix A for discussion of these differences.

front. However, the French alone in Europe are fielding an anti-radar version of Martel, whereas the US has two air-to-surface weapons and one surface-to-surface operational anti-radar weapon dating from the mid-1960s. The French missile is apparently optimized for ship radars and could be considered an anti-shipping rather than defense suppression. At least one writer [22] has suggested that the absence of defense suppression weapons for the RAF (which bought only the electro-optical version of jointly developed Martel) is explained by their doctrine of *evading* SAM defenses rather than suppressing them. However, an air base *denial* weapon JP-233 is a major US/UK cooperative development program. Interestingly enough, all production of the French air base denial weapon Durandal was reported as being exported in 1979.

Missiles for defending against ground forces are almost all focused upon the immediate tank battle--a variety of front-line anti-tank missiles for US, UK, France, and FRG. The size and composition of planned European NATO air forces, including consideration of MRCA and such weapons as Jumbo and Strabo, does not suggest an overriding interest in carrying the combat to the enemy rear via guided weapons such as Maverick and Assault Breaker. The US is, thus, clearly the leader in developing missile weapons that can attack the enemy reserve and support forces and disrupt his logistics.

As for naval forces, US requirements are driven by defense of carrier task forces, thus we have the "Standard" missile air defense series, F-14 and Phoenix, Harpoon, and the Aegis system with its radars and computers to tie all the weapons together. France and the FRG, on the other hand, have stressed individual unit action, since their navies have smaller vessels and tend to operate in closed seas. The UK has traditionally been a high seas Navy, but has been withdrawing from that role in the last decade.

In summary, the US has tended more to concentrate on the demanding and expensive tasks involving theater warfare. France and the FRG have tended more towards small unit conflict, with the UK in between. The US certainly has not universally dominated tactical missile development in terms of interest in all areas. On the other hand, it is clear that France, the FRG, and the UK have not shown high interest in all mission areas and that they have avoided the more expensive areas.

The evidence on mission emphasis and missile types has, in this chapter, been based on a review of historical and strategic considerations. In the next chapter we take a quantitative view in measuring interest and capability.

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Chapter V

MEASURES OF NATO TACTICAL MISSILE INTEREST

In Chapter I, the express and implied assumptions of the "family of weapons" concept for cooperation in weapons development were discussed. Chief among those is the "one for the US, one for Europe" approach which implies roughly equal interest in use of and capability to produce the weapons in question. The history of weapons development sketched in Chapter IV suggests that in tactical missiles that approach is not the case for most weapon types. To focus more clearly on this issue, we will examine quantitative measures of interest and capability for the three major powers of Europe as compared to the US over the period 1949-1978.

The measures we use for these comparisons are as follows:

(1&2) The *number of different weapons* developed, by type, over the post-World War II period and the *number* to be produced in the 1980s.

(3) The estimated *value of expenditures* for research and development, by type, over the period.

(4&5) The *volume of production*, in units, by type over the period and the *current rate of production*, by type.

(6) The potential *domestic weapons demand*, by type, as measured by national forces of appropriate character.

(7) The *industrial development capability* as measured by the number of potential prime contractors with capability to develop each type of missile.

A. THE NUMBER OF WEAPONS

The number of different weapons developed over the period can offer only a crude measure of interest. The Europeans developed 42 weapons compared to 35 in the US (Table 18). The early

Table 18. NEW TACTICAL MISSILES BY TYPE AND DEVELOPING COUNTRY, 1949 TO PRESENT

	Type												All Types		
	Surface-to-Air (land)		Surface-to-Air (sea)		Air-to-Air		Anti-Tank		Air-to-Surface		Surface-to-Surface				
Period	US	Europe	US	Europe	US	Europe	US	Europe	US	Europe	US	Europe	US	Europe	Total
1949-53	1	0	1	0	0	0	0	0	0	0	0	[illegible]	2	2	2
1954-58	3	3	2	0	3	3	0	3	0	0	0	0	8	9	17
1959-63	0	1	0	3	0	1	0	2	2	3	0	0	2	10	12
1964-68	2	3	2	1	0	1	1	2	2	1	0	0	7	8	15
1969-73	1	1	0	0	1	0	2	2	2	0	0	1	6	4	10
1974-78	0	1	1	1	0	2	0	1	1	2	1	1	3	8	11
1979-	3	1	0	0	0	1	1	0	2	1	1	0	7	3	10
TOTAL	10	10	6	5	4	8	4	10	9	7	2	2	35	42	77

Source: Appendix C. This table does not include all systems shown in Table 13 or all the variations in Table 17. See Appendix A for discussion of differences. It includes guided projectiles and guided bombs such as Copperhead and the GBU-15 family, but excludes missiles designed and deployed primarily with nuclear warheads such as Lance and Pershing.

US interest in surface-to-air missiles, both land and sea based versions, is apparent. The early US long range weapons were matched only by those of the UK. Except for Patriot, the land weapons developed in the last decade on both sides of the Atlantic have stressed field army defense rather than fixed site defenses. The absence of numbers of "new" US sea-based surface-to-air missiles is due to the fact that the US Navy's current "Standard" weapons are evolved variations on the earlier Terrier/Tartar missiles--and not counted as new in the table.

Turning to air-to-air weapons, we see a continuing interest in new weapons in Europe. As long as national fighter aircraft continue to be produced, one can expect that national weapons for those aircraft will be provided. Thus, the British produced two generations of IR missiles for their British-built Lightning fighters, but modified the US Sparrow for their later US-produced F-4K fighters. The French continue to provide both new versions of IR and radar-bombing weapons for their French-built Dassault fighters. As with sea-based surface-to-air missiles,

the US has relied mainly on evolution of 1950s families for its short and medium range missiles. It is only recently that wholly new concepts are being explored for this mission.

The European lead in anti-tank guided weapons can be seen in the table. The Europeans were into production with second generation weapons before the US fielded its first in Shillelagh in the 1960s. In this field, the appearance of new tank armor technology in the 1970s has rendered all of the weapons in this list fairly ineffective against future tanks, with a corresponding premium on developing effective guided weapons of new design. The current weapons, both European and US are, however, effective against almost all existing Soviet tanks.

The air-to-surface guided weapons data suggest equal numbers of programs. However, the earlier European missiles were relatively unsophisticated wire-guided or visually tracked radio-command guided weapons. Among the US weapons of the 1964-1968 period were the first effective operational missiles using TV guidance, laser homing, and radiation homing (anti-radar). Moreover, the Europeans have placed somewhat more emphasis on anti-ship missiles.

The surface-to-surface weapons picture, by excluding the US nuclear capable battlefield weapons such as Pershing, Sergeant, Corporal, and Lance, emphasizes the anti-shipping weapons in which the Europeans have shown an earlier and more active interest. The first US weapon to have been designed as an anti-surface ship weapon[1] was Harpoon, which will eventually equip many more ships than its European counterparts Exocet and Otomat.[2] Harpoon is also being deployed as an air launched and (submersible) submarine launched anti-surface ship missile. The

[1]There is a version of the Standard Missile which has been modified for surface-to-surface missions, as well as terminal radar homing version for air-to-surface use. Both of these are anti-ship in their terminal effect.

[2]Based on intentions as described in Reference [1, pp. 153-165, 189-192, 570-576, 656-683].

other surface-to-surface weapon shown for the US is Copperhead, which has no European equivalent and none appears to be planned.

Since the early peak associated with the development of surface-to-air and air-to-air missiles in 1954-1958, the pace of development in terms of new weapons of all types on both sides of the Atlantic can be seen to have remained fairly steady. The figures on numbers of programs offer some background, but we turn now to more useful measures.

B. DEVELOPMENT SPENDING

A better measure of effort and interest than numbers of weapons is estimated development spending by missile type (Table 19). What shows up in the surface-to-air category is the $5.4 billion US expenditure on high-to-medium altitude systems to counter manned bombers. Additional billions were invested in the anti-missile systems that followed the earlier anti-bomber systems. To some degree, the British attempted similar high altitude interceptor systems[1] but, as their spending indicates, stopped short of such systems as the US Patriot, which will cost over $2 billion for development. One can also see that only the US and UK have developed man-portable systems.

In air-to-air weapons, the US is the only country to develop a long-range weapon in Phoenix. The seeming heavy investment in short-range weapons reflects the US early lead (and its own duplicative effort) in infrared homing anti-bomber weapons in the Sidewinder and Falcon families. Short range in these was not an objective of design (as it is today in Magic) but an obstacle to be overcome. The current tentative NATO division of effort--an advanced short range air-to-air missile (ASRAAM) to be designed in Europe for all NATO use and an advanced medium

[1] In the famous British Defense White Paper of 1957, the so-called Sandys Report, the British government propounded the view that manned fighter aircraft were no longer necessary, since missiles would do the interceptor task in future [2, p. 6].

Table 19. TACTICAL MISSILE DEVELOPMENT SPENDING, MAJOR NATO POWERS

(Millions of 1979 Dollars)

Missile Type	Country					Total All Four
	US	Europe				
		France	FRG	UK	Total	
Surface-to-air (land)						
Man Portable	288	--	--	58	58	346
Short-to-medium	301	256	121	248	625	926
High-to-medium	5,403	450	--	1,264	1,714	7,117
Total	5,992	706	121	1,570	2,397	8,389
Country Share (%)	71.4.	8.4	1.4	18.7	28.6	100.0
Surface-to-air (sea)						
Short range	29	--	--	30	30	59
Medium range	952	604	--	338	942	1,894
Long range	783	--	--	470	470	1,253
Total	1,764	604	--	838	1,442	3,206
Country Share (%)	55.0	18.8	0.0	26.1	45.0	100.0
Air-to-air						
Short range	1,272	590	--	462	1,052	2,324
Medium range	656	748	--	194	942	1,598
Long range	426	--	--	--	--	426
Total	2,354	1,338	--	656	1,994	4,348
Country Share (%)	54.1	30.8	0.0	15.1	45.9	100.0
Anti-tank						
Man Portable	175	780	260	282	1 322	1,497
Heavy	573	384	--	330	714	1,287
Heliborne	163	30	--	--	30	193
Total	911	1,194	260	612	2,066	2,977
Country Share (%)	30.6	40.1	8.7	20.6	69.4	100.0
Air-to-surface						
Anti-radiation	580	189	--	--	189	769
Other	1,551	478	313	406	1,197	2,748
Total	2,131	667	313	406	1,386	3,517
Country Share (%)	60.6	19.0	8.9	11.5	39.4	100.0
Surface-to-surface						
Land	140	--	--	--	--	140
Anti-ship	477	1,095	--	--	1,095	1,572
Total	617	1,095	--	--	1,095	1,712
Country Share (%)	36.0	64.0	0.0	0.0	64.0	100.0
GRAND TOTAL	13,769	5,604	694	4,082	10,380	24,149
Country Share (%)	57.0	23.2	12.9	16.9	43.0	100.0

Source: Tables 25-28.

range weapon (AMRAAM) by the US for all NATO use--better reflects the differing doctrinal interest of the US and European air forces than does the spending totals. But the *distribution* of spending in the table supports the thesis of such a difference.

The last two categories of R&D spending, anti-tank and surface-to-surface (especially anti-ship weapons), underline differences in interest. The US, indeed by its spending alone, has not given man-portable anti-tank weapons as significant a place in US tables of equipment and presumably in US anti-tank tactical doctrine, as have the Europeans. And while the Europeans have adapted anti-tank weapons designed for ground launch, like SS.12 and Hot for helicopter delivery, only the US has a new weapon specifically designed for helicopter carriage in Hellfire. One can note, also the European interest in anti-shipping missiles--with French Exocet and Franco-Italian Otomat and British Sea Skua. When coupled with the fact that airborne versions of all these are in production or development, along with the West German air-launched Kormoran missile, one needs then to know that the US Harpoon is going to foreign navies at an apparently greater rate than to the US Navy to conclude that US interest in an immediate need for the surface-to-surface version is not very strong.[1]

C. PRODUCTION, 1949-1978 AND RECENT

The successful development of a weapon by a country is usually equivalent to a decision to produce it, use it, or sell it. In terms of the long-run production of weapons, by type, Table 20 gives the overall picture. The US preponderance

[1]The US Air Force is the only major NATO air force element that does not have the mission of attacking ships at sea, this being a US Navy prerogative. Moreover, the US Navy failed to develop an anti-shipping missile until well into the 1970s. Of a total of 480 estimated AGM/RGM 84A produced in 1978, figures in Reference [3, pp. 190-241] show at least 249 export deliveries.

Table 20. TACTICAL MISSILE PRODUCTION: 1949-1978, NATO COUNTRIES[a]

Missile Type	US	Europe			
		France	UK	Germany	Total
Surface-to-air (land)	178,000	5,000[d]	28,000	500[c]	33,500
Surface-to-air (sea)	17,000	500[e]	13,000	--	13,500
Air-to-air	211,000	15,000	5,000[b]	15,000[c]	35,000
Anti-tank	410,000	338,000[d]	7,500	200,000[f]	545,500
Air-to-surface (anti-radar)	15,000	750[h]	--	--	750
Air-to-surface (all others)	250,000[j]	20,000	250[k]	350	20,600
Surface-to-surface (sea)	1,400	1,200	--	--	1,200

[a]Figures are rounded to nearest 1,000 or nearest 50, as appropriate, References [4 through 11]. Excludes significant production of anti-tank weapons by Italy and air-to-surface by Norway.

[b]Estimated by assuming 6 missiles produced per UK Lightning fighter aircraft AAM station.

[c]Licensed production of foreign designed weapon excludes coproduction with France.

[d]Excluded German coproduction.

[e]Assumes 40 missiles per Masurca launcher rail, 6 per Crotale launcher tube.

[f]Excluded coproduction with French.

[g]Assumes 2 Martel AS.37 missiles per combat aircraft with capability for missile.

[h]Includes guided bomb guidance kits.

[i]Estimates Martel AJ.168 production. See Footnote g.

in production of land-based SAMs, air-to-air missiles, and air-to-surface weapons shows that the number of variations developed within a type (and the spending for that purpose) does not necessarily correlate with the number of copies produced. Notice also that in anti-tank weapons the Europeans hold the production lead. But the US is almost alone in anti-radar weapons.

The US production preponderance in land-based SAMs and air-to-air weapons is explained, in part, by the same cause as the European anti-tank lead. In all cases, the production leader was also the first to develop an effective weapon, so that production has gone on for a longer time. In addition, having the

first and often the best weapon meant that the US--or France--became the world's supplier of that weapon type for a while, thus adding sales and production. In the US case, especially with air-to-surface weapons, but extending to others, the actual consumption of weapons in combat or training has generated a requirement for volume production. The European producers have not had any combat calling for sophisticated weapons since World War II.

The picture is not greatly changed when we look at recent production rates for the various types in Table 21. The reversal

Table 21. ESTIMATED 1978 TACTICAL MISSILE PRODUCTION RATES (Units Per Year)

Missile Type	US[a]	European				
		France[b]	FRG[c]	UK[d]	Consortium[e]	Total
Surface-to-air (land)	8,250	300	--	2,700	300	3,300
Surface-to-air (sea)	1,200	12	--	315	--	327
Air-to-air	4,000	1,450	--	400	--	1,850
Anti-tank	48,000	800	1,200	250	28,000	30,250
Air-to-surface	13,000	1,200	300	--	--	1,500
Surface-to-surface	240	150	--	--	150	300

[a]Reference [11], passim.

[b]Reference [4, pp. 528-530], Reference [5, p. 182].

[c]Reference [5, pp. 110, 241], estimated from context.

[d]Reference [5, pp. 169, 191, and 230]. Some estimates on basis of probable requirement in terms of numbers of UK and foreign operated British built systems, as derived from Reference [12].

[e]Reference [5, pp. 152ff, 241-243], Reference [4, pp. 528-530], and Reference [13, p. 128].

of the US/European relation in anti-tank weapons may be due to recent and unusually high export order production of Tow.

D. REQUIREMENTS

As we have already indicated in earlier chapters, the Europeans approach weapons standardization from the viewpoint

that volume production is possible for them only if they have access to export markets for weapons. However, it is useful to estimate what sort of markets might exist solely in terms of domestic arms requirements. In Table 22, we show some indexes

Table 22. VALUE OF FORCE INDEXES FOR TACTICAL MISSILES

Missile Type/ Force Index	US	European			
		France	FRG	UK	Total
Surface-to-air (land)[a] Ground Forces (000)	966	324	336	161	821
Surface-to-air (sea) Ship Launchers	763	26	3	460	489
Air-to-air Missile Stations	15,800	1,150	4,500	2,500	8,150
Anti-tank Ground Forces (000)	966	324	336	161	821
Air-to-surface Attack Aircraft (first line)	3,000	400	920	500	1,820
Surface-to-surface[b] Launchers (anti-ship)	1,028	126	190	162	478

[a]Short range and man-portable only.

[b]European, US, and foreign naval units in commission or planned and reported by *Jane's* as *scheduled* for Harpoon or Exocet installations are included and weighted by the number of launch rails or cells.

Source: Ground forces: Reference [12].
Ship-based SAM and SSM launchers: Reference [1].
Air-to-air missile stations and first line attack aircraft: References [1] and [12].

of own requirements for each country. For instance, those surface-to-air missiles used to defend forces in the field should be roughly proportional to the size of ground forces; the number of sea-based SAMs should relate to the number of launcher rails on ships in the various navies, and so on. These simple counts do reveal some relations not apparent in other measures. For instance, the combined Three Power ground forces are about 85 percent as large as those of the US, but attack and fighter aircraft forces are only about 60 percent as large. The

surface-to-surface figure is based on reported installations existing and planned by all the four navies.[1]

Thus, the various measure of interest, past and present, present a fairly coherent picture of: US domination of expensive long range surface-to-air systems, but not in the mobile short range air defense weapons; a US lead that is challenged by France in short and medium range air-to-air missiles; rough parity in anti-tank weapons between the US and Europe; a dominating US presence in air-to-ground weapons (except for anti-shipping where US interest is quite recent); and a perhaps changing picture from European to US leadership in sea-based surface-to-surface weapons.

E. CONTRACTORS

As to the capability to develop and produce new weapons, the contrast between the European "chosen instrument" process and US competitive procurement is not accurately reflected in the relative numbers of organizations active in each field of development and production. Table 23 shows that there is no large difference in the number of potential producers for each type of missile between the US and the European powers combined. But these European prime contractors constitute only a small list of seven:[2] Aerospatiale, Matra and Ruelle Arsenal in France; British Aerospace, Short Brothers, and Harland in the UK; and Messerschmitt-Bölkow-Blohm (MBB) and Bodenseewerk Geratetechnik (BGT) in West Germany. Furthermore, while each of 11 US contractors *could bid* on any development or production contract, in the European countries national development and

[1]If only installations (launcher positions) existing in 1978 were used, the US/Europe ratio would be *1:14*. The US had only three 8-cell Harpoon launchers at sea in that period, the very beginning of the fitting-out process.

[2]One of these, BGT, is a licensee for an earlier Sidewinder modification, and will produce US AIM-9L for European sales—so that the effective list of chosen instruments is no more than six. In addition, Ruelle Arsenal produces Masurca only, and at a low rate, so that the list reduces to five, in effect.

Table 23. NUMBER OF PRIME CONTRACTORS[a] FOR TACTICAL MISSILES BY TYPE AND COUNTRY

Missile Type	US	European			
		France	FRG	UK	Total
Surface-to-air (land)	7	2	1	2	5
Surface-to-air (sea)	2	2	--	2	4
Air-to-air	4	1	1	1	3
Anti-tank	4	1	1	1	3
Air-to-surface	4	2	1	1	4
Surface-to-surface	4	2	--	--	2
Any Type[b]	11	3	2	2	7

[a]Prime contractor for development and/or production of a tactical missile system in last 10 years. Euromissile is not counted as a prime contractor--Aerospatial and MBB are each counted as a prime for jointly produced weapons.

[b]Counts each corporate entity only once.

Source: Appendix E.

production responsibility for any system *is assigned* exclusively to one or another producer by the governing authority. The 11 US firms[1] represent successful *bidders* on either a development or production contract for a major system in the fields listed.

Another difference is the size of the production contract between the US and European firms. Weapon-by-weapon, the US production contracts averaged about $124 million each in 1978. By comparison, the European contracts averaged about $18 million. Taking all weapons together, the 11 US producers divided an estimated $2,233 million,[2] for an average of $203 million each in tactical missile production. Six of the seven[3] European

[1]Boeing Aerospace, Ford Aerospace, General Dynamics, Hughes Aircraft, LTV, McDonnell Douglas, Martin Marietta, Raytheon, Rockwell, Texas Instruments, and Western Electric. The firm and missile type lists are shown in Appendix E.

[2]Production numbers by type multiplied by procurement costs as reported in Reference [11].

[3]BGT is not included in the estimate, since they were not yet producing AIM-9L in the period considered.

producers divided an estimated $385 million[1] for an average of $64 million each in tactical missile business in the same period. Were one to add estimated annual R&D spending, the relative resource outlays would change slightly in the European direction.

F. OVERALL US/EUROPE COMPARISON

The comparisons between the US and Europe can be summarized by converting the measures shown above to an index basis. In Table 24, we show the comparison of European interest and capability with the US. Reviewing the measures, weapon type by weapon type, the following limitations apply.

Table 24. RELATIVE MEASURES OF US/EUROPEAN TACTICAL MISSILE INTEREST AND CAPABILITY BY TYPE
(Value of US Measure = 1.00)

Missile Type	Value of Measure for UK, France, FRG Combined						
	Number of Different Weapons			Units Produced			
	Developed	In Production 1980s	Estimated R&D Expenditures	1949-1978	1978	Demand as Sized by Own Forces	Prime Contractors
Surface-to-air (land)	0.90	1.25	0.40	0.19	0.40	0.85	0.71
Surface-to-air (sea)	0.83	0.50	0.82	0.79	0.27	0.64	2.00
Air-to-air	2.00	1.00	0.85	0.17	0.46	0.52	0.75
Anti-tank	2.50	2.00	2.27	1.33	0.63	0.85	0.75
Air-to-surface	0.89	1.00	0.65	0.08	0.12	0.61	1.00
Surface-to-surface (sea)	1.00	2.00	1.77	0.86	1.25	0.46	0.50
Overall Measure[a]	1.17	1.11	0.75	n.a.	n.a.	n.a.	0.64

[a]The overall measure in each case is the sum of six US measures divided by the sum of the six European measures. It is not the sum of the six measures divided by six. Thus, the types with more activity are given more weight.

Source: First and third through seventh columns calculated from Tables 18 through 23, respectively. Second column from References [3-14] of Chapter IV.

1. Surface-to-Air (Land) Missiles

The apparent equality of types of current weapons in Europe conceals the absence of either a long-range weapon or a man-portable fire-and-forget weapon equivalent to the US

[1]Production numbers by type multiplied by price data from Reference [16], supplemented by prices of US analogies where date were not reported.

Stinger.[1] Thus, the duplication in battlefield weapons represented by French Crotale and Roland and UK Rapier and Tigercat makes up the total.

2. Surface-to-Air (Sea) Missiles

The anomaly here is in the large number of European producers. Actually, the four in Europe are the two "chosen instruments" in France and in the UK. In the US, except for Raytheon's Sea Sparrow, General Dynamics has maintained its monopoly in naval SAMs because the current generation is a set of modifications of the original Terrier/Tartar weapon. Compatibility with existing ship fits--which are expensive--partly dictates this kind of continuity.

3. Air-to-Air Missiles

The seeming European parity in weapon types hides the absence of any European production of (or interest in) a long-range weapon such as US Phoenix. The latter is tied to the need to protect carriers which support the doctrine of strike carrier warfare against land targets in areas that are defended by Soviet land based aircraft. But the availability of both short and medium range French weapons of modern capability whose production is low, compared to the US, probably represents more of an investment on behalf of selling French combat aircraft (with compatible missiles) in the export trade than it does an effort to secure US-level sales volumes for missiles themselves. (Although

[1]Since completion of our research, France has announced the development of a Stinger equivalent, i.e., a man-portable fire and forget surface-to-air missile with an infrared seeker and a range of four kilometers. Known as SATCP or Sol Air Tres Courte Portee (surface-to-air very short range), the missile is to be deployed in 1985. The French Army and Air Force are to buy around 10,000 units. But—according to one of its executives—Matra considers that exports take priority over French defense needs because Matra must have total production of 20,000 to 40,000 to justify the program. See *Aviation International*, Oct. 15, 1980, p. 19.

the latter result would probably not cause unhappiness for the French.)

4. Anti-Tank Missiles

The figures reflect not only a well established European interest in anti-tank guided missiles for their own forces, but a strong export market to areas shut off by US political restrictions on US arms exports.

5. Air-to-Surface Weapons

The absence of European production--in volume significant when compared to the US--is not easy to interpret. It may suggest that the European view of the air forces contribution to any ground war in Europe is quite different than that of the US. It may reflect a much less serious view of the likelihood of the occurrence of European war in which there would be a prolonged campaign requiring air-to-ground attacks in volume or it may reflect unwillingness to go into the expensive area of air-to-ground warfare in more than a nominal way (mainly ballistic weapons).

6. Surface-to-Surface (Sea Based) Missiles

The indexes show that the interest in SSMs for anti-shipping is high in France and the FRG, as measured by the proportion of ships having SSM installations, but was fairly low in the US and Britain--until the last few years.

G. CONCLUSIONS

As a concluding characterization, the US has spent more developing fewer missiles, but called on a more varied industrial base to do that development. It would appear that the conditions conducive to a successful family of weapons policy exist primarily in the anti-tank, surface-to-surface anti-shipping, and

short range air defense fields. Here, if the choice of developers were based on the index values, it could go either to Europe or the US. However, one must note that the three European powers, despite US-European talks about a family of weapons approach to anti-tank weapons, have agreed to proceed with their own cooperative program to develop "third generation" anti-tank weapons [15, p. 3]. Surface-to-surface weapons are not even included in Dr. Perry's list; the focus has been on NATO air-to-air weapons field, with an MOU assigning the short range weapon to Europe and the medium range to the US.

While the US has gone so far as to cancel specific ASRAAM projects of the Services, public statements by Dr. Perry have indicated the US is not really depending on the European weapon [16, p. 29]. In a recent public symposium, Dr. Perry emphasized that the US would continue research on short range missile seeker technology: "...it will be their [European] decision which seeker to use and which company would supply that seeker. But...we plan to continue to sponsor vigorous development in the field of focal plane arrays and other technologies that would be useful in a short range air to air missile, as well as other systems." [17, p. 29]

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Chapter VI

DUPLICATE DEVELOPMENT PROGRAMS: PAST, PRESENT, AND FUTURE

Given the many almost identical missiles of similar purpose and technology developed and produced by the four major powers in NATO over the last 30 years, one would expect that the Alliance could have done with fewer types. Some idea of the potential duplication may be had by comparing the 77 systems developed by the NATO Allies to a sort of hypothetical minimum. The results of such an exercise would give a "no duplication" versus "actual" development record for NATO something like the following:

Missile Type	Expected Number	Actual Number
Surface-to-air (land)	9	20
Surface-to-air (sea)	9	11
Air-to-air	7	12
Anti-tank	8	14
Air-to-surface	8	16
Surface-to-surface	2	4
TOTAL	43	77

The "expected" number is a judgment based on the number of separate "missions" in each category and the number of "generations" since the first appearance of a weapon in that subcategory.[1] As a quantitative measure of duplication, it is illustrative rather than analytical. A better measure of duplication, however, is the approximate cost savings that would have been achieved by eliminating duplicate development projects. In this chapter we make such an estimate. Following that, we estimate potential future savings by comparing the planned program of tactical missile development cooperation with a hypothetical minimum program that would have involved complete cooperation.

A. MINIMUM PROGRAM APPROACH

We estimated past redundancy in development spending by first estimating what was actually spent by the Alliance and then specifying a "minimum" expenditure as that which would have been necessary to produce the smallest set of operational missiles which, in our judgment, would have met the perceived NATO mission requirements. The cost of redundancy, or the

[1]The procedure (and reasoning) follows:

In each of the surface-to-air categories and in the air-to-air category there are three classes of weapons—short, medium, and long-range, if you will. In anti-tank weapons only two types, man-portable and heavy, existed until the development of helicopter borne weapons in the late 1960s and early 1970s. Surface-to-surface anti-shipping weapons, were developed late and consist only of land and anti-ship versions. Thus, if we assume a possible three generations of land SAMs, we would expect a minimum of nine systems; similarly for sea-borne SAMs. For AAMs, only short and medium range have been in existence for three generations, the long-range weapon is only now approaching a second generation—thus, seven systems would be the expectation, and similarly for anti-tank weapons a record of eight systems since the second generation airborne weapon will be embodied in Hellfire. In the air-to-surface category, we distinguish those which are powered, beginning with Bullpup and ending with TV-guided Maverick, with three generations possible; then free-fall weapons such as Walleye and Paveway, with three generations; and the radiation homing weapon such as Shillelagh and Martel, with two generations possible. For surface-to-surface, assuming only one generation, we would expect two systems to have been developed.

potential saving, is the difference between the two estimates. The minimum program that we posit represents an attempt to specify a program that is both realistic and feasible. More specifically, we pose the following questions:

(1) Given the range of missions required by NATO as indicated by the latest weapons in the field or ready for production today, which of these sets actually developed are necessary to satisfy those missions?

(2) Given this set of non-duplicative weapons that were the predecessor operational weapons, which appear to be the essential development steps leading to today's chosen weapons?

(3) What were the estimated development costs of the projects in this "minimum" program?

(4) What was the development cost of the remaining "redundant" weapons?

Added to those estimates is a further estimate of Alliance development spending which may have gone into technology base research and into weapons programs that were aborted without producing operational weapons.

The definition of "redundancy" is a matter of judgment and the results will necessarily be debatable. The concern in this report is to classify duplication on a mission, not a technology basis, although technology will be considered. Thus, if two long-range surface-to-air weapons are observed to have been fielded at about the same time and to serve roughly the same purpose, one will be said to be redundant. Which one is to be called redundant, in this context, is not made on cost-effectiveness grounds although it might be done if the requisite numbers were available. Even then the results would be subject to considerable argument.

The judgments of redundancy in this report are based on a combination of (1) earliest IOC; (2) numbers fielded; (3) history of modification and improvement (persistence); and (4) evidence of success or failure. Further, to allow for some redundancy

that would be normal, considerable allowance is made in the cost estimate of the total program for both aborted developments and technology base research and development. Finally, it should be kept in mind that if there had been cooperation, weapons that are in the program would probably be different from the weapons actually developed. Thus, our attempt to create a minimum program cannot be taken literally. Rather, it is an indication of what *might* have happened with complete cooperation.

The first category (earliest IOC) accounts for many choices of US weapons, except in the anti-tank and anti-surface ship field. The second (number fielded) would weight the US too heavily, although not always, so it was discounted to some extent. The third (persistence) helps explain the choice of Sidewinder, Sparrow, and Exocet.[1] The fourth category is exemplified by Condor, Shillelagh, and Falcon. Condor, besides its high cost, was a weapon in the wrong service--a long-range anti-shipping weapon for a Navy apparently uninterested in the anti-shipping mission *at that cost*. Shillelagh was not only wedded originally to a vehicle without a future, Sheridan, but associated with an embarrassing design mistake in the M60EA2 main battle tank turrets and having a serious operational difficulty which made it unusable from a tank in hull defilade position.[2]

That Falcon, originally designed to carry a nuclear warhead, persisted with conventional warheads in competition with Sidewinder and Sparrow (which seem to us to have opened on to more promising lines of development) into redundancy, is the contention. Technical experts may disagree on all these choices, but since the objective is to estimate "unneeded" spending and

[1]There are particular complexities in the choice of Exocet-see note at end of Table 30.

[2]This can be read between the lines of Congressional Testimony in 1969, 1970, and 1971. See especially the *Appropriations Hearings 91st Congress, 1st Session, Part 5*, pp. 81-115; *2nd Session, Part 5*, p. 83; *92nd Congress, 1st Session, Part 5*, p. 232, and the *House Armed Services Committee Hearings on Military Position...1971*, pp. 7675, 7760.

because of the use of analogies and CERs in the cost estimating techniques, exchanging the entries between categories in the following tables will not have a great effect on the division between "minimum" and "redundant" spending totals. It will affect the division among countries as to who is responsible for the redundancy, but we do not stress this aspect in this report. Rather, the emphasis has been on quantitative measures of redundancy by missile type for the whole Alliance.

B. COST METHODOLOGY

In the last 20 years, the US Defense Department has identified development spending, at the least, from the stage of engineering development by weapon. Thus, we have direct estimates for most US weapons, which we have adjusted for price changes so that all estimates are in 1979 dollars. For other US weapons and for foreign weapons (where no such development cost information was available) we have used a set of cost estimating relationships (CERs) developed at the Institute for Defense Analyses [1, pp. 57-60, B-3ff and 2, pp. 51, 74ff] and used to estimate development costs for Soviet missiles. These CERs use physical characteristics of the weapons as a basis for estimating cost. For example, the Reference [1] estimating relationship for surface-to-air missiles is

$$C = 431\ K^{.46}$$

where

C = development cost in millions of 1979 dollars

K = weight in thousands of kilograms.

From Appendix D, Table D-1, ("Descriptive Characteristics"), we find the weight of the Nike Hercules MIM-14/B to be 4,720 kilograms. Substituting in the CER, we get

$$\begin{aligned} C &= 431(4.72)^{.46} \\ &= 431(2.0418) \\ &= 880 \text{ million dollars (1979 dollars).} \end{aligned}$$

This figure is shown in Table 25, which gives the development cost estimates for US tactical missiles and is identified as coming from source (1), the CER. The list of sources of all the estimates are to be found in the notes at the end of Table 28. Tables 25 through 28, below, comprise the source from which Table 23, in the previous chapter, was computed.

These CERs--as with all CERs (and as our footnote on page 108 indicates for Paveway)--frequently fail to depict what really happened for specific weapons programs. A CER is an average that includes, even for those weapons in the data set used in the original calculation, considerable variation. One must be even more careful in applying the CER to weapons very different from those in the data set. It is also possible that technology changes will cause the CERs to be in error as time passes. Moreover, so-called historical costs that are official may be in error. Changing accounting systems and alternate definitions of development are likely to influence what may currently be counted as the actual development costs.

Further, we discussed only development costs and--as is ordinarily done in these cost analyses--treated them as if they can be separated from production costs. This is, of course, not literally true. There are likely to be redesigns to meet the larger number of variations in military requirements and in engineering tooling manufacturing and logistic support practice. We have implicitly assumed that possible *added* development costs that were caused by a common weapons programs would at least be offset by savings in production and logistics due to standardization.

Finally, we have made no attempt to estimate differential costs in the various countries. In the earlier years of the period considered, salaries and wages were lower in Europe. The dollar was overvalued relative to the European currencies, considering what the currencies could buy in their own countries.

Table 25. DEVELOPMENT COST ESTIMATES: US TACTICAL MISSILES

Missile Type	Designation	Cost (Millions of 1979 $)	Source
Surface-to-air (land)			
Man-Portable			
Redeye	FIM-43A	47	(1)
Stinger	FIM-92A	241	(2)
SUBTOTAL		288	
Short-to-medium Range			
Chaparral	MIM-72C	27	(2)
US Roland	MIM-115	274	(2)
SUBTOTAL		301	
High-to-medium			
Bomarc	CIM-10A/B	1,041	(1)
Nike Ajax	MIM-3	453	(1)
Nike Hercules	MIM-14B	880	(1)
Hawk	MIM-23	338	(1)
Improved Hawk	MIM-23B	291	(2)
Patriot	MIM-104	2,400	(2)
SUBTOTAL		5,403	
TOTAL		5,992	
Surface-to-air (sea)			
Short Range			
Seasparrow	RIM-7H	29	(2)
SUBTOTAL		29	
Medium Range			
Terrier	RIM-2	489	(1)
Tartar	RIM-24	349	(1)
Standard 1	RIM-66	114	(2)
SUBTOTAL		952	
Long Range			
Talos	RIM-8	534	(1)
Standard 2	RIM-67	249	(2)
SUBTOTAL		783	
TOTAL		1,764	
Air-to-air			
Short Range			
Sidewinder	AIM-9B	137	(1)
Sidewinder	AIM-9D	312	(1)
Sidewinder	AIM-9G/H	29	(3)
Sidewinder	AIM-9L	95	(2)
(Subtotal)		573	
Falcon	AIM-4A/E/F	252	(1)
	AIM-4B	234	(1)
	AIM-26	213	(1)
(Subtotal)		699	
SUBTOTAL		1,272	
Medium Range			
Sparrow	AIM-7C	462	(1)
Sparrow	AIM-7D/E/F	194	(2)
SUBTOTAL		656	
Long Range			
Phoenix	AIM-54A	352	(2)
Phoenix	AIM-54C	74	(2)
SUBTOTAL		426	
TOTAL		2,354	

Sources at end of Table 28, p. 107.

(Continued)

Table 25. (Concluded)

Missile Type	Designation	Cost (Millions of 1979 $)	Source
Anti-tank			
Man-Portable			
Dragon	FGM-77A	175	(2)
SUBTOTAL		175	
Heavy			
TOW	BGM-71A	243	(2)
Shillelagh	MGM-51A	330	(1)
SUBTOTAL		573	
Heliborne			
Hellfire	MGM-114A	163	(2)
SUBTOTAL		163	
TOTAL		911	
Air-to-surface			
Anti-radiation			
Shrike	AGM-45	322	(1)
Harm	AGM-88	258	(2)
SUBTOTAL		580	
Other			
Bullpup	AGM-12A/B	197	(1)
Maverick	AGM-65A/B	258	(1)
	AGM-65C	97	(2)
	AGM-65D	64	(2)
Walleye 1 and 2	AGM-62	69	(3)
Condor	AGM-53	478	(1)
Hobos	E/O Kits	140	(4)
Paveway	KMU Series Kits	140	(4)
GBU-15	GBU-15	108	(3)
SUBTOTAL		1,551	
TOTAL		2,131	
Surface-to-surface			
Land			
Copperhead	MIM-712	140	(4)
SUBTOTAL		140	
Anti-ship			
Harpoon	AGM/RGM-84	477	(3)
SUBTOTAL		477	
TOTAL		617	
GRAND TOTAL - US		13,769	

Sources at end of Table 28, p. 107.

Table 26. DEVELOPMENT COST ESTIMATES: FRENCH TACTICAL MISSILES

Missile Type	Cost (Million of 1979 $)	Source
Surface-to-air (land)		
Short-to-medium		
Crotale	135	(1)
Roland I	121	(1)
SUBTOTAL	256	
High-to-medium		
Parca	450	(1)
SUBTOTAL	450	
TOTAL	706	
Surface-to-air (sea)		
Medium Range		
Masurca	604	(1)
SUBTOTAL	604	
TOTAL	604	
Air-to-air		
Short Range		
AA.20	153	(1)
R.511	200	(1)
Magic R.550	237	(1)
SUBTOTAL	590	
Medium Range		
R.530	315	(1)
Super 530	433	(1)
SUBTOTAL	748	
TOTAL	1,338	
Anti-tank		
Man-Portable		
Entac	272	(1)
SS.10	272	(1)
Milan	236	(1)
SUBTOTAL	780	
Heavy		
SS.11	30	(5)
SS.12	30	(5)
Hot	324	(1)
SUBTOTAL	384	
Heliborne		
Harpon	30	(5)
SUBTOTAL	30	
TOTAL	1,194	
Air-to-surface		
Anti-radiation		
Martel AS.37	189	(6)
SUBTOTAL	189	
Other		
AS.11/12	60	(7)
AS.20	163	(1)
AS.30	195	(1)
AM.38	--	(8)
AM.39	60	(9)
SUBTOTAL	478	
TOTAL	667	
Surface-to-surface		
Sea		
Exocet MM.38	730	(14)
Otomat	365	(10)
SUBTOTAL	1,095	
TOTAL	1,095	
GRAND TOTAL - France	5,604	

Sources at end of Table 28, p. 107.

Table 27. DEVELOPMENT COST ESTIMATES: UK TACTICAL MISSILES

Missile Type	Cost (Millions of 1979 $)	Source
Surface-to-air (land)		
Man-Portable		
Blowpipe	58	(1)
SUBTOTAL	58	
Short-to-medium		
Rapier	123	(1)
Tigercat	125	(1)
SUBTOTAL	248	
High-to-medium		
Bloodhound 1/2	632	(1)
Thunderbird 1/2	632	(11)
SUBTOTAL	1,264	
TOTAL	1,570	
Surface-to-air (sea)		
Short Range		
Seacat	30	(5)
Medium Range		
Seaslug	338	(12)
Long Range		
Sea Dart	470	(1)
TOTAL	838	
Air-to-air		
Short Range		
Firestreak	213	(1)
Red Top	249	(1)
SUBTOTAL	462	
Medium Range		
Skyflash	194	(13)
TOTAL	656	
Anti-tank		
Man-Portable		
Vigilant	282	(1)
Heavy		
Swingfire	330	(1)
TOTAL	612	
Air-to-surface		
Other		
Martel AJ 168	189	(6)
Sea Skua	217	(1)
TOTAL	406	
GRAND TOTAL - UK	4,082	

Sources at end of Table 28, p. 107.

Table 28. DEVELOPMENT COST ESTIMATES: FRG TACTICAL MISSILES

Missile Type	Cost (Millions of 1979 $)	Source
Surface-to-air (land)		
Roland II	121	(1)
Anti-tank		
Man-Portable		
Cobra/Mamba	260	(1)
Air-to-surface		
Other		
Kormoran	313	(1)
GRAND TOTAL - FRG	694	

Sources:
(1) Estimate with CER (Cost Estimating Relationship of Reference [1] and characteristics given in Appendix D.

(2) Reference [3].

(3) Reference [4].

(4) Assumed to be twice the cost of Walleye. However, see footnote p. 108.

(5) A modification of an existing weapon. Assumed to be approximately equivalent in technology to AIM-9G modification or AIM-7H modification, therefore, cost assumed to be the same, rounded.

(6) Martel estimated at $378 million using CER. Half assigned to French AS.37 and half to UK AJ.168.

(7) Estimated at twice the SS.11 to SS.12 cost.

(8) AM.38 included under MM.38.

(9) Change of AM.38 to AM.39 assumed to be analogous to change from US Maverick C to Maverick D and similar in cost.

(10) Assumed to be half Exocet estimate.

(11) No weight data, assumed to be equal to Bloodhound in cost, since performance is identical.

(12) Cost assumed to be similar to Hawk, since performance is similar.

(13) Cost assumed to be same as AIM-7D/E/F, since Skyflash is UK development base for AIM-7C.

(14) Used CER as (1) above. The estimate appears high compared to Harpoon. An estimate by analogy might have been more appropriate in this case.

More recently, the payroll costs have probably been comparable, while the dollar could be considered undervalued. The use of US CERs for European costs implies that the US/European's comparisons should be considered only as rough indices of effort based on the weapons developed rather than a measure of actual resources consumed. For all these reasons, we attach little importance to any specific estimate. Rather, it is the aggregate measure of the cost of redundancy which is better than previous estimates based on casual evaluation and certainly better than no estimate at all.

We have limited consideration to the four major powers, which covers 95 percent or more of the development cost for tactical missiles outside the Soviet bloc. The practical problem of separating the accounting for Hot, Milan, and Roland cooperative development programs has led us to treat the two spending streams as one in later discussion, despite their separation in the table.

As the source notes to Table 28 indicate, other procedures were used for estimating costs. This happened when a direct figure was lacking and the CER procedure gave unrealistically high values. In the case of the electro-optical and laser guidance kits for guided bombs in the US Hobos and Paveway programs, the recorded expenditure for a similar but less extensive effort under the Walleye 1 and 2 program was doubled to generate a development cost estimate for Hobos and also for Paveway.[1] In the case of some foreign programs, such as the SS.11, SS.12, AS.11, and the AS.12 anti-tank weapons that represented modifications of the Entac and SS.10 originals, the CER technique (which assumes a "new" weapon) yielded estimates that were much

[1]The reported development costs of the Paveway development program (as discussed in [18] which was called to our attention after the research was completed, total approximately $8 million (1979 dollars). The difference between this exceptionally successful program and the CER estimate suggests that eliminating duplication is not the *only* way of reducing Alliance development costs.

too high to be credible, given the probable levels of total defense expenditure in France in the period. Thus, the development cost estimate was derived by using the known cost of a US modification to a tactical missile of what was judged to be about the same gross change in performance.

Similarly, in the case of the air-launched AM.39, which is a modification of the AM.38, which is an air-launched version of the MM.38 Exocet surface-to-surface missile. The cost estimate was obtained by assuming this modification to be analogous to the Maverick D development after Maverick A/B and C had been developed. This leads to a fairly heavy weighting of the Exocet cost on its initial surface-to-surface version. No doubt the subsequent air-to-surface variants were anticipated during the early development.

In other cases, such as the MM.38 Exocet itself, which has an air-to-surface version, the AM.38, the value resulting from applying the CER for a surface-to-surface missile provides an estimate seemingly large enough to include the AM.38 version. In the case of Otomat, which has about half the performance of Exocet, we assumed an R&D expenditure of half the Exocet amount, and have included the unknown Italian contribution in the French spending, since it is a NATO weapon. Other NATO weapons such as Penguin, Aspide, etc., have not been included, since our focus is on the four major powers.

Among British weapons, we have used the CER estimate for Bloodhound, for which we have weight data, as the estimate for Thunderbird, for which weight data is missing. Since the latter has the same reported performance, the procedure seems appropriate. Since Seacat is a version of Tigercat, we use the "similar" technology improvement argument and apply the "AIM-9G to AIM-9H" estimate. For Seaslug, we noted the performance similarities to US Hawk and used the latter estimate as a proxy for R&D spending. Skyflash represents the same sort of technical

step as that between AIM-7C and AIM-7D/E/F, for which we have direct estimates.

The necessity of using analogies and estimating equations argues against drawing fine distinctions about individual projects on the basis of the numbers above. Circumstances can vary considerably from project to project. The validity of overall figures, as used in Tables 19 and 29, rest on the assumption that the resource costs of similar activities tend to be similar in all Western industrial countries, countries which engage in extensive international commerce in materials and technology. A more detailed analysis might take into consideration the relative cost of capital, technical manpower, production manpower, and raw materials in the four countries.

C. MINIMUM AND REDUNDANT TACTICAL MISSILE PROGRAMS

Given the cost estimates above and using the characteristics and IOC data in Appendix D, we were able to divide the national projects into a "minimum program" as defined earlier in the chapter, with the remaining projects considered as redundant. Table 29 shows the results by missile type, while the specific systems selected are shown in Table 30.[1]

Of the total of $24.15 billion of spending for completed systems, $10.43 billion was classified as redundant, or 43.2 percent of the total. The largest percentage of redundancy is in the anti-tank field, with 60 percent of estimated duplicate spending. But the largest absolute amount is in air-to-air missiles, with an estimated $2.46 billion of duplicate spending. It should be noted that more than one-fourth of this is a result of including the US-developed Falcon family in redundant systems.

[1]Reference [5], which became available after our choices were made, gives French views that Exocet and US Harpoon (p. 23), AS.30 and Maverick (p. 20), Milan and Dragon (p. 19), and Hot and Tow (p.19) are directly competitive (with the French weapon superior in every case). Our judgments on redundancy were somewhat but not entirely different.

Table 29. MINIMUM AND REDUNDANT NATO TACTICAL MISSILE PROGRAMS: SUMMARY OF DEVELOPMENT SPENDING

(Millions of 1979 Dollars)

Missile Type	Spending			Percent Redundant
	Minimum	Redundant	Total	
Surface-to-air (land)				
Man-portable	288	58	346	16.8
Short-to-medium	396	530	926	57.2
High-to-medium	5,403	1,714	7,117	24.1
TOTAL	6,087	2,302	8,389	27.4
Surface-to-air (sea)				
Short range	59	--	59	0.0
Medium range	952	942	1,894	49.7
Long range	783	470	1,253	37.5
TOTAL	1,794	1,412	3,206	44.0
Air-to-air				
Short range	810	1,514	2,324	65.1
Medium range	656	942	1,598	58.1
Long range	426	--	426	0.0
TOTAL	1,892	2,456	4,348	56.5
Anti-tank				
Man-portable	780	717	1,497	47.9
Heavy	303	984	1,287	78.3
Heliborne	163	30	193	15.5
TOTAL	1,246	1,731	2,977	58.1
Air-to-surface				
Anti-radiation	580	189	769	24.0
Other	1,246	1,502	2,748	54.7
TOTAL	1,826	1,691	3,517	48.1
Surface-to-surface				
Land	140	--	140	0.0
Anti-ship	730	842	1,572	53.6
TOTAL	870	842	1,712	49.2
GRAND TOTAL	13,715	10,434	24,149	43.2

Table 30. MINIMUM AND REDUNDANT TACTICAL MISSILE PROGRAMS: DETAIL

(Cost in Millions of 1979 Dollars)

Surface-to-Air (land)						
	Man-Portable		Short-to-Medium		High-to-Medium	
Program	Weapon	Cost	Weapon	Cost	Weapon	Cost
Minimum	Redeye Stinger Total	47 241 288	Chaparral Tigercat Rapier Roland II Total	27 125 123 121 396	Bomarc Nike Ajax Nike Hercules Hawk Improved Hawk Patriot Total	1,041 453 880 338 291 2,400 5,403
Redundant	Blowpipe	58	Crotal Roland I US Roland Total	135 121 274 530	Parca Bloodhound Thunderbird Total	450 632 632 1,714

Surface-to-Air (sea)						
	Short Range		Medium Range		Long Range	
Program	Weapon	Cost	Weapon	Cost	Weapon	Cost
Minimum	Seacat Sea Sparrow Total	30 29 59	Terrier Tartar Standard I Total	489 349 114 952	Talos Standard 2(ER) Total	534 249 683
Redundant	None		Seaslug Masura Total	338 604 942	Sea Dart	470

Table 30. (Continued)

Air-to-Air						
	Short Range		Medium Range		Long Range	
Program	Weapon	Cost	Weapon	Cost	Weapon	Cost
Minimum	Sidewinder Family	573	Sparrow Family	656	Phoenix Family	[illegible]
	Magic R.550	237				
	Total	810				
Redundant	Falcon Family	699	R.530	315	None	
	AA20	153	Super 530	433		
	R.511	200	Skyflash	194		
	Firestreak	213	Total	942		
	Red Top	249				
	Total	1,514				

Anti-Tank						
	Man-Portable		Heavy		Heliborne	
Program	Weapon	Cost	Weapon	Cost	Weapon	Cost
Minimum	SS.10	272	SS.11	30	Hellfire[a]	163
	Entac	272	SS.12	30		
	Milan	236	Tow	243		
	Total	780	Total	303		
Redundant	Dragon	175	Shillelagh	330	Harpoon	30
	Vigilant	282	Swingfire	330		
	Cobra/Mamba	260	Hot	324		
	Total	717	Total	984		

[a]Specifically designed for helicopter carriage. Other general purpose and anti-tank weapons such as SS/AS.11 and SS/AS.12 have been adapted for helicopter launch.

Table 30. (Concluded)

	Air-to-Surface			
	Anti-Radiation		Other	
Program	Weapon	Cost	Weapon	Cost
Minimum	Shrike	322	Bullpup	197
	Harm	258	Walleye	69
	Total	580	Maverick	419
			GBU-15	108
			Kormoran	313
			Paveway	140[a]
			Total	1,246
Redundant	AS.37 Martel	189[b]	Condor	478
			Hobos	140
			AS.11/12	60
			AS.20	163
			AS.30	195
			AM.39	60
			AJ.168 Martel	189[b]
			Sea Skua	217
			Total	1,502

[a]See footnote p. 108.

[b]One half of combined AS.37/AJ.168 Martel estimate.

	Surface-to-Surface			
	Land		Anti-Ship[a]	
Program	Weapon	Cost	Weapon	Cost
Minimum	Copperhead	140	Exocet	730
Redundant			Harpoon	477
			Otomat	365
			Total	842

[a]Exocet was selected over Harpoon because of its earlier IOC as a surface-to-surface weapon. In this mode, performance is similar and cost is quite different (Exocet approximately $350,000; Harpoon approximately $900,000). As an air-to-surface weapon, performance and the concept of operations with the two weapons differs considerably--the choice of which weapon to select in the 1980s might be different. By 1990 one could probably look back and see more clearly which "family"--Exocet or Harpoon--would be thought redundant.

This sort of duplication, arising in part from separate US service development programs, has been important only in air-to-air and air-to-surface weapons fields. It will not be eliminated by any NATO cooperative programs.

The second most important area of duplication, in terms of spending, is in land-based surface-to-air weapons. Note that more than three-fourths of this is in long-range weapons--a field in which the Europeans have not been developing any weapons since the 1960s.

Thus, the US concentration in its family of weapons cooperation in the development of air-to-air weapons and anti-tank weapons would appear to be justified by past history of duplications, as well as by the indexes of interest described in the preceding chapter.

D. OTHER MISSILE-RELATED R&D SPENDING

The grand total of tactical missile R&D spending of $24.1 billion is not the full amount spent. Two other sources of expenditure inevitably accompany and, indeed, are essential to the development of operational tactical missiles. One source is the unsuccessful development attempts which result in projects being aborted prior to development of an operational weapon. To estimate this cost we resort, again, to US experience.

Using the cancelled tactical missile programs from 1949-1965 gives us a figure which we can compare with the estimated spending on completed tactical missile development programs.[1] We have chosen to adopt, as a rule of thumb, the most prevalent value in recent years--about one-third in additional spending. Assuming that this is an inescapable cost on both sides of the

[1]Although data were available from the source [6, p. 563-586] for 1966-1969, we excluded them to avoid problems with the fall off at the end that is inherent in such figures, i.e., spending on a cancelled program in a given year cannot be identified until the programs are cancelled.

Atlantic and is related to all types of programs, we add to our total of $24.1 billion another $8.0 billion for aborted projects. This gives us a total for advanced stages of development of $32.1 billion (Table 31). If we assume the $8 billion is distributed to minimum and redundant programs in the same proportion as completed programs, the $8 billion would represent $3.5 billion of "redundant" programs and $4.5 billion as part of the "minimum" program.

In addition, we assume all four countries maintain labs, research organizations and test facilities, etc., which

Table 31. ESTIMATED REDUNDANT R&D SPENDING ON NATO TACTICAL MISSILES
(Billions of 1979 Dollars)

Category	All Spending	Redundant Spending	
		Dollars	As a Percent of Total Spending
Completed Projects			
Surface-to-air (land)	8.4	2.3	3.6
Surface-to-air (sea)	3.2	1.4	2.2
Air-to-air	4.3	2.5	3.9
Anti-tank	3.0	1.7	2.6
Air-to-surface	3.3	1.7	2.6
Surface-to-surface	1.9	0.8	1.2
Total Completed	24.1	10.4	16.2[a]
Aborted Projects	8.0	3.5	5.5
Total All Projects	32.1	13.9	21.7
Infrastructure	32.1	13.9	21.7
TOTAL	64.2	27.8	43.3[a]

[a]Does not add because of rounding.

constitute the R&D infrastructure and which are not included in the costs associated with specific weapons. The relationship between the portion of the total US defense RDT&E budget, and that included in programs of the type we have been counting as development cost of systems, was obtained by comparing the

categories for engineering development and operational systems development to the total for recent years, as seen in Table 32. If we assume European practices are similar to US, in terms of resource costs, we can estimate another portion of the total tactical missile development cost--R&D infrastructure--which will have the effect of doubling the outlays for successful and aborted development programs.

Thus, we calculate over $64 billion in tactical missile spending, of which we have identified $13.9 billion, or about 21.7 percent, as very probably redundant (Table 31 again). To this one could possibly add some unknown portion of the estimated

Table 32. DERIVATION OF INFRASTRUCTURE RATIO: RDT&E COSTS

Fiscal Year	Column 1 US RDT&E Spending Operational System Development Engineering Development	Column 2 ($ Millions) All Other	Ratio (1) ÷ (2)
1974	4,293.5	3,901.3	1.10
1975	4,360.2	4,275.6	1.02
1976	4,826.8	4,701.3	1.03
1976	1,135.4	1,261.8	0.90
1977	5,674.4	5,267.9	1.08
1978	5,689.3	6,213.4	0.92
TOTAL	25,979.6	25,621.3	1.01

Sources: References [7, p. A-1], and [8, p. A-2].

infrastructure cost that might have been "saved" over the 30 year period, if redundancy had been avoided by some form of planned cooperation. The upper limit on such saving would be something over the 43 percent represented by the development cost redundancy, before adding in infrastructure costs. For the reasons we discussed earlier in the chapter (see especially pp. 102-103), these estimates should be treated only as indicators of redundancy, not as a literal estimate of savings.

Over the period the total spending of $64.2 billion would amount to over $2 billion per year. If, for the sake of simplicity, we divide the savings by 30 (that is, 1949 through 1978), potential savings would range from $450 to $900 million per year. It might be possible to add some refinement to the estimate by examining minimum and redundant spending by five year periods and by taking into consideration that some of the funds will be spent after 1978 (Table 33). However, it seems better--given the fluctuations shown--to estimate possible future savings by examining recent developments and plans for the future, rather than refining our estimate of what might have been. We turn to that examination in the next section.

E. FUTURE PROGRAMS

Future potential savings through cooperation can also be estimated but is even more speculative than the estimate of past

Table 33. MINIMUM AND REDUNDANT TACTICAL MISSILE SPENDING BY FIVE YEAR PERIOD
(Billions in 1979 Dollars)

Period	Spending			Percent Redundant
	Minimum	Redundant	Total	
1949-53	0.84	0.08	0.92	8.7
1954-58	3.76	2.36	6.12	38.6
1959-63	1.27	2.62	3.89	67.4
1964-68	1.12	1.70	2.82	60.3
1969-73	2.21	0.97	3.18	30.5
1974-78	2.10	2.02	4.12	49.0
1979 and Beyond	2.42	0.68	3.10	21.9
TOTAL	13.72	10.43	24.15	43.2

Source: Cost estimates in Tables 25-28 and spending envelope from Reference [2].

savings foregone. There are reports (Table 34) of over 25 new missile systems and 20 other modifications, improvements, and

Table 34. NATO TACTICAL MISSILE DEVELOPMENT WORK 1980s AND EARLY 1990s[a]

Missile Type	Country				
	US[b]	US(c)	E(c)	F	UK
Surface-to-air (land)					
Man-portable	I	-	-	N,I	I
Short range	I	-	I	I	I
High-to-medium					
Hawk type	A	-	N	-	-
Patriot type	I	-	-	-	-
Surface-to-air (sea)					
Short range	-	N,N	N	I	-
Medium range	I	-	-	-	-
Long range	N	-	-	-	-
Self-initiated	N	-	-	-	-
Air-to-air					
Short range	I	-	N	I	-
Medium range	N	-	-	I,N	I
Long range	I	-	-	-	-
Helicopter	A	-	-	A	-
Anti-armor[c]					
Man-portable	N	-	N	-	-
Medium to heavy	I	-	N	-	-
Helicopter launched	N	-	-	-	A
Wide area	N	-	-	-	-
Air-to-surface (land)					
Anti-radiation	I	-	-	-	N
General purpose	I	-	A	-	-
Guided bombs	I	-	-	-	-
Medium range/standoff	N,N	-	-	N	-
Airfield attack	-	N	-	-	-
Air-to-surface (sea)					
Anti-radiation	-	-	-	I	-
Other	N	-	-	-	-
Surface-to-surface (or-to-subsurface)					
Land	N	N	-	N	-
Anti-ship	N	-	N	I	N
Anti-submarine	N	-	-	-	-

[a]Excludes Patriot, Stinger Post, Harm and other weapons included in earlier analysis which will enter the forces in the early 1980s.

[b]Based on current policy one could expect the US to offer most of these weapons for dual or coproduction in Europe. In that sense many of them are or will become cooperative.

[c]Although called "anti-tank" elsewhere in the study, the more general term "anti-armor" is appropriate for future weapons and probably for past ones too.

ABBREVIATIONS FOR COUNTRIES:

US(c) = US cooperative development with 1 or more European countries.

E(c) = Cooperative program between or among 2 or more European countries.

F = France

ABBREVIATIONS FOR TABLE ENTRIES:

A = Adaptation of another missile type.

I = Improvement

N = New weapon

Source: References [9-18].

adaptations of existing weapons proposed for introduction in 1982 and beyond. Included are a number of new types such as the SIAM or Self-Initiated Anti-aircraft Missile for submarine defense and the helicopter air-to-air missiles.

These systems would cost about $10 billion to develop over the next 10 years. This figure would, since it accounts for all planned systems, include aborted developments. Another $10 billion would be added for infrastructure giving a total of $20 billion (Table 35). This come to $2 billion per year in 1979 dollars or about the same as the historical average. Eliminating redundant programs would reduce the spending to $15 to $17.5 billion saving $2.5 to $5 billion or $250 to $500 million per year--the range depending on assumptions about savings in infrastructure spending if the redundant systems were not developed. To put this figure in perspective, a recent FRG estimate of the proposed French-FRG-US tactical combat aircraft

Table 35. MISSILE DEVELOPMENT SPENDING 1980-1990

(Billions of 1979 Dollars)

Complete Program	
Item	Estimate
Total Program Spending[a]	10
Infrastructure	10
TOTAL	20
Annual Rate	2

Without Duplication		
Item	Estimate	
	Low	High
Total Program Spending[a]	7.5	7.5
Infrastructure	7.5	10.0
TOTAL	15.0	17.5
Annual Rate	1.5	1.75

[a]Includes both completed programs and aborted developments.

is that it would cost $3.5 to $6 billion to develop.[1] Elimination of this one aircraft would save, in development costs alone, the equivalent of a massive cooperation program covering all tactical missiles.

The prospects for cooperation in the future are not improving. The US continues to plan for development of a full array of tactical missiles. The Europeans, though short of funds, continue to pursue a number of weapons which duplicate existing and proposed US weapons. Examples are the French intermediate range air-to-air missile and a man-portable surface-to-air missile with an infrared seeker. The US has been left with a monopoly in the development of theater oriented weapons aimed at defeating massed armor or intercepting aircraft attacks at long distance. Still the US insists on covering the whole array of missile types including those in which the Europeans have considerable depth and experience such as the medium and heavy anti-tank missiles.

One of the problems is that the basic technology of missiles overlaps missile types. Although this has always been true, the new advanced technology shows great promise, in third generation weapons, in perfecting infra-red and millimeter wave seekers to see through haze and smoke or to work at night and in poor weather. Whether the US should share this technology with the European countries by transferring the expensively won technology or by selling the components that embody it is a serious policy question for the future.

[1]These estimates became available after our research was completed. The lower figure appeared in *Aviation Week & Space Technology*, May 5, 1980, p. 16. The higher figure, $6 billion, was reported in *Aviation Week & Space Technology*, August 18, 1980, p. 18.

The judgments about this sharing are complex involving questions about continuity of development efforts, leakage to the USSR, and sales of weapons to countries outside the Alliance. The military gains from sharing would be substantial if they should lead to an increase in capability of forces in the field from common logistics and inventory. Even without sharing in development such gains are possible if the Europeans were willing to buy US systems. But it appears that such sharing is unlikely. The Europeans, for their part, are unwilling to allow the US a monopoly on the most advanced research on missile seekers for all the reasons cited earlier in the study. They are concerned about their independence from the US, the state of their advanced technology and freedom to sell to countries outside the Alliance.

For the future we know the US has offered a number of systems to the Europeans (Table 36). Additional systems could be expected to be offered to those countries. Whether they will be taken up is open to question. Judging by the past, the FRG

Table 36. MISSILE PROGRAMS OFFERED TO EUROPEANS

Hellfire
Harpoon
Sidewinder AIM-9L
High Speed Anti-Radiation Missile (HARM)
Advanced Medium Range Air-to-Air Missile (AMRAAM)
GBU-15 Glide Bombs
General Support Rocket System (GSRS)
NATO Sea Sparrow Surface Missile System (NSSMS)
Sparrow AIM-7M
Rolling Airframe Missile (RAM)
Low-Altitude Airfield Attack System (LAAAS)
Copperhead
Patriot
Improved Tow
Improved Hawk
Stinger/Stinger Post
Maverick

Source: Reference [13, pp. 64-86].

will be willing to take licenses on weapons in which they are not able to cooperate in development with France and the UK. Now that the Euromissile consortium includes the UK, three country cooperation seems to be likely with less European duplication among themselves but with considerable duplication and competition across the Atlantic.

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Chapter VII

ALTERNATIVE APPROACHES TO NATO ARMS COOPERATION

A. CONFLICTING GOALS

The major thrust of this study has been to show that the four major arms producing powers of NATO approach their defense problems in different ways and with widely varying resource contributions to defense. It argues that, without substantive compromise, the promise of major gains in efficiency by providing arms to NATO through cooperative development and production is not likely to be achieved.

In approaching NATO arms questions the US emphasizes the centrality of interdependence of interests while the European powers, particularly France and the UK, stress the importance of their independence and sovereignty. This includes independence from the US as well as the USSR. France, the UK and to a lesser extent the FRG, view their independent industrial arms capability as both supportive of and as a measure of that independence. The US--at least in its declared policy--sees no need of independent arms capability in all areas for each country, stressing instead that interdependence makes the capability of one the capability of all.

The US encourages European cooperation, particularly three power cooperation, as a prerequisite to transatlantic arms cooperation, thus appearing in agreement with Europeans who stress cooperation among themselves. Neither the US nor Europeans appear to act according to this policy; the US has been willing to strike separate deals at the expense of European unity,

while the Europeans have found it difficult to agree on cooperative programs, except on a limited ad hoc basis.

The emphasis on the two-way street may make it appear that the US accepts Europe as an equal in arms production and development, a position the Europeans say is necessary to any transatlantic dialogue. However, the US has a defense industry that is twice as large as the European industry. The European industry is itself split into many smaller markets, thus making it difficult to envision the practical conditions under which the US and the Europeans could be considered equals in the area of arms development and production.

The European insistence that the transatlantic dialogue not interfere with European cooperation is difficult to achieve because (1) there is limited European cooperation to begin with, and (2) most US sales to Europe are to the minor powers who would lose bargaining power if the US left the European market. The US has shown no interest in abandoning its smaller Allies to the major European powers. It has, however, shown willingness to work with the major as well as smaller NATO countries in coproduction arrangements involving European industry.

The French and British insistence on a two-way street for European/US arms trade is irrelevant, given the level of UK and particularly French purchases from the US: There is little traffic in either direction. But the very size of the US defense budget is bound to result in the US being the dominant force in most, though certainly not all, weapons areas.

The US insistence on unilaterally limiting third country sales of licensed products inhibits the participation of France and the UK in agreement under the family of weapons approach. Both are now heavily dependent on such sales for both political and economic reasons.

Finally, the European powers stress the interoperability of equipment in the field, seeing no compelling reason for having standardized equipment which they fear will be American. The US, on the other hand, stresses the gains in cost and effectiveness from standardized NATO forces, though the current proposal for dual production lines has, to some extent, weakened the argument about cost savings and reduced the potential for saving.

We examined the area of tactical missiles because this is the area that has been stressed in the family of weapons and because this seemed to offer in microcosm all the political, economic, technical and military problems faced in NATO weapons development and acquisition as a whole. Moreover, it included in land-based air defense at least one of the most critical areas for weapons cooperation, being both costly and an area where cooperation *in the field* is absolutely essential if the mission is to be carried out successfully.

In tactical missiles, the history, geography, military tradition, and spending levels have all helped determine the emphasis of each of the four major producers. These considerations have led to the relative emphasis of the US on air warfare, naval air defense, and fixed-site air defense, while the European land powers bordering enclosed seas--France and the FRG--have emphasized anti-tank weapons, mobile air defense and anti-ship weapons. Finally, the UK has emphasized air defense of the island and naval warfare.

In addition to differing missions and doctrines, capabilities are different. In particular, the US has spent four billion dollars more on tactical missile R&D, as well as many billions more on related research such as strategic missiles, radars and other electronics. The US has produced three times as many missiles as the other three major European countries combined.

Nevertheless, because of the differing mission emphasis and differing R&D and production capability, the European countries--if they do not dominate--at least match US capabilities in some areas. In particular, mobile surface-to-air, anti-tank and anti-ship weapons have all been developed and then produced in numbers and probably in quality to match the US. On the other hand, it may be that because much of the future of tactical missiles appears to depend on advanced electronics, the US radars and advanced guidance and seekers will be critical in the next generation of missiles.

We found that past cooperation might have saved from $14 to $28 billion or 22 to 43 percent of the total tactical missile spending since World War II. The range depends on what one assumes about the policies of the four countries concerning their research and development infrastructure, i.e., would (or should) they have been maintained at their historic levels even with maximum standardization of weapons. For the future we found potential savings of about the same percentage level.

In summary we find a wide variation in interest and capabilities among the four countries. The US tends to dominate in R&D spending and production in most but not all areas. Even in areas that the US does not dominate, it tends to be at least equal the Europeans. Much of R&D and production capability of the four countries appears aimed at export markets, although such sales appear more important for France than for the other countries.

B. REQUIREMENTS FOR A US POLICY

US policy for cooperation in weapons development and acquisition must deal with the following problems:

- Differing national missions and conflicting military doctrine;
- Differing stages of development, production and deployment for the various weapons;
- Differing R&D and production capability and depth;
- Determination of all four countries to maintain their own independent and fairly broad technology base;
- Differing enthusiasms for and dependence on third country sales, and differing limitations on such sales.

The one thing it cannot do is make the countries more and less interdependent at the same time. If a new policy of increased cooperation is to be undertaken, it must be one that moves in the direction of increased interdependence. If such is unacceptable, then the existing policy of the ad hoc arrangements for licensing and coproduction is the reasonable course to follow. If, however, increased interdependence is acceptable to the four powers, then an agreement is possible, but only if there is compromise on the other issues. We suggest in the next section a mechanism for bringing about such compromise.

C. THREE APPROACHES TO COOPERATION

We began the study by describing two approaches to saving money and achieving standardized weapons through cooperative R&D and acquisition:

- Ad hoc licensing and coproduction
- Family of weapons

We now suggest a third approach:

- A broad-gauged agreement on the model of the multilateral trade negotiations which might cover all weapons or might be limited, in the beginning, to a broad weapon type or mission area.

1. Ad Hoc Licensing and Coproduction

This approach can continue to work on a case-by-case basis. It is limited by all the problems and conflicting views toward cooperative programs that have been cited. Nevertheless, major aircraft and air defense programs have been successfully handled in this manner. France has shown only limited interest in such agreements with the US, not participating in the aircraft programs but participating in air defense. Thus, the French are not as critical as the FRG and the UK to the continued success of this approach. European interest in new large-scale coproduction agreements will be tested in the current negotiations on the Patriot Air Defense System.

2. Family of Weapons

This approach is so limited that the success will not make much difference either in saving R&D costs or increasing standardization. The most expensive air defense and all aircraft systems are excluded. Indeed, if every system so far mentioned in US policy statements were in fact to be included in an agreement, the saving would not be more than $3 billion out of the $200 billion to be spent on R&D in the next decade by the four major producers. But applicability of this approach is limited to an even smaller number of items, and is unlikely to save more than several hundred million dollars over the whole decade for all four countries. Even these few agreements are threatened by the conflicting interests of the four powers and even the small savings could be threatened by added costs in transferring manufacturing technology.

3. Broad-Gauged Multilateral Weapons Agreement[1]

It appears that the conflicts in NATO arms development and acquisition are not peripheral issues that can be easily side-stepped. In particular, the most critical areas must be compromised by the four major producers if significant gains are to be achieved. Such a compromise might involve a broad agreement that:

(a) Covers critical issues of doctrine and the nature of the weapons to carry out warfare under that doctrine;

(b) Includes weapons in all stages of development, giving credit for those decisions which have already contributed to standardization and increased force effectiveness;

(c) Tends to divide work according to mission interest and industrial capability;

(d) Includes an agreement on the maintenance of an R&D technology base;

(e) Specifies limitations on selling of licensed products outside of NATO that would allow France and the UK to continue to sell as they do now--only limiting sales of certain specific advanced technology products;

(f) Sets ground rules for international competition of consortia;

(g) Sets ground rules for international agreements on production standards, military specifications, testing, auditing and a number of other Executive and DoD policies, regulations, and practices.

This third approach to cooperation in development is to attempt a broader and more comprehensive agreement than has been tried to date, but one that is not necessarily inconsistent with either the family of weapons concept or with the special arrangements for individual weapon systems. What is different is the fact that these agreements would be reached within a broad framework and would be, in the long run, tied together.

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[1]This proposal is similar to those advanced by Callaghan [1] and more recently by Frost [2].

The model for such an agreement is MTN or multilateral trade negotiation.[1] While MTN is aimed at increasing the economic benefits of international trade, a multilateral arms trade agreement would aim at both the direct economic benefits of trade and the more difficult to calculate military benefits of arms standardization. Many of the issues involved in the MTN--tariffs, government procurement codes, subsidies, product standards, licenses, and special sector problems--are also problems in arms trade. In addition, an arms development and production agreement would have to deal with the unique association that nations make between their arms industry and their sovereignty. But the effects of arms trade on employment, on high technology research, and on manufacturing technology are still analogous to issues that had to be handled in the recent MTN agreement and, thus, may have paved the way for agreements on arms.

An attempt at a comprehensive agreement would have to treat many issues that are left unsettled in a mission-by-mission agreement. It would allow for--indeed, it would require--broad compromises within the US government and industry that are not possible in the more limited agreements. It is possible, however, that--after four years of pursuit of limited agreements and two years of discussing the family of weapons--a new approach may be appropriate.

A comprehensive agreement might cover all weapons, or it might cover one type of weapon such as all tactical missiles. It would aim to resolve conflicts within the US government, among the Europeans and across the Atlantic through an agreement that is broad enough to allow tradeoffs among the many diverse goals that are affected by arms development and production.

[1]For an introduction to the MTN, see [3], especially Chapters II and III. Our more recent research (performed with Stephen Shaffer) leads us to greater skepticism about the relevance of MTN than we express in this study.

D. COMPARISON OF THE THREE APPROACHES

For the first two approaches, licensing and family of weapons, individual or pairs of candidates for standardization are considered in isolation. In the third, however, one looks for an overall framework within which these individual candidates might fit (see Table 37). In the first approach--ad hoc licensing--these individual candidates are subject to specific agreements to license for production. However, in the second--family of weapons--two, or perhaps several individual candidates are subject to an agreement that is at once specific and vague. It is specific in the weapons covered, but (1) vague in that competitive development that must be given up is difficult to define so that the immediate exchange being agreed upon is vague; and (2) the decision to procure the weapons is so far in the future that the commitments under the agreement must be contingent on a large number of unknowns involving strategy, tactics, technology, budgets, third country sales, policies, etc.

Each agreement must stand on its own, which would be difficult even if we were contemplating only a few agreements. But a large number, perhaps 20 or 30 such agreements, would be needed eventually if the approach is to result in significant savings. Although it is possible to construct general guidelines which each separate agreement is to follow, these agreements are independent of each other and no overall measure or control exists for deciding whether the total system is working. Moreover, the critical decision points are so far off that it will be five or ten years before one can see significant positive results.

The licensing and coproduction approach, although it is limited in its applicability, does allow the individual countries to take advantage of the strengths and weaknesses within the Alliance in development and production. On the other hand, the

Table 37. COMPARISON OF THREE APPROACHES TO COOPERATIVE DEVELOPMENT AND ACQUISITION OF NATO WEAPONS

Type of Agreement	Coverage	Stage	Nature of Exchange	Enforcement	US Internal Conflicts
Ad Hoc Licensing	Single system at a time	At or near end of development	Payment for license including data package to produce for own use and limited sale	Immediate and specific	Agreements limited to those involving minimal conflict with other national policies
Family of weapons	Limited mission and type of vehicles	Beginning of development	Same, but two-sided, also agree to eliminate competitive development	Cannot be tested for many years	Forces US to resolve many broad conflicts
Comprehensive/MTN	All weapons in a broad mission area or all weapons	All stages	Balance complex interests	Based on broad aggregates which can be measured on a continuing basis	Forces US to settle some conflicts before negotiating; allows broad tradeoffs for others

Type of Agreement	Intra-European Conflicts	Transatlantic Conflicts	Type of Specialization	Cost Saving	Standardization
Ad Hoc Licensing	May cause conflict between participating and non-participating countries	Agreement limited to areas with minimal conflict	Only where demonstrated to be appropriate	Limited development	Limited
Family of Weapons	Leaves large producer/small producer split. Forces compromise among large producers	Must settle broad conflicts in each limited area	Arbitrary division by mission and weapon type	Limited development, perhaps a little more than licensing	Same as above
Comprehensive/MTN	Requires broad tradeoffs	Requires broad tradeoffs	Takes advantage of broad demonstrated capability	Production and development	Comprehensive standardization

family of weapons, if it is to be successful, must cover so many missions that it ends up treating these missions as if all the major producing countries had a roughly equal interest in them.

This points out a limitation in the current concept of the family of weapons: It is being applied to one of the simpler "families" that are most likely to succeed and, thus, leaves out the most interesting and important ones. Land-based surface-to-air weapons should probably be a major category to be considered for cooperation because of their expense and because of the interaction of such systems in the field. Whereas different models of air-to-air or anti-tank missiles, for example, may be used without significant mutual interference, air defense is a mission in which strategy and tactics must be coordinated. Thus, a family that included at least the following--Patriot, I-Hawk, Rapier, Roland, Divad, Gepard, and Stinger--would offer significant long-term gains both in cost saving and in effectiveness provided the approach could include production agreements. Such a family might also include communications, IFF, and other air defense issues beyond the weapons themselves. But this broader family would require the US and its Allies to review and coordinate their air defense requirements rather than going off in different directions as they now do. Moreover, it would integrate the development, acquisition, and deployment programs of the four powers.

Indeed the NATO Long Term Defense Program Task Force 5 on air defense might have had the potential for forming the basis of such an agreement. However, the stress was on aircraft identification, communications, command, and control. The weapons emphasis was on increasing capability and interoperability but not on standardization.[1] Further, from the decisions

[1]For discussion of the Task Force 5 report see former Secretary Brown's annual reports *Rationalization/Standardization Within NATO* [4, pp. 17-20] and [4, pp. 19-20].

on air defense systems that have been considered and taken since then, we can see little evidence that development and procurement of a long term cooperative defense program is being pursued in a comprehensive way that would lead to standardization or specialization in development and production. Rather, recent events--the tentative US approach to Roland, the US purchase of Rapier, the US offers of licensed production of Stinger and Stinger Post, the French refusal to participate in the AWACS, the UK choice of its own Nimrod, the French decision to develop its own man-portable surface-to-air missile, and most important, the tentative European approach to Patriot while threatening to develop a European alternative--all indicate an ad hoc approach which includes cooperation but not standardization. It is not a comprehensive approach to cooperation that would lead to much greater standardization or to major cost savings.

A comprehensive agreement on air defense is but one possible example. Others might involve complete missions and weapon types, or that might cut across all missions and weapon types. Such an agreement would be difficult to negotiate because it would involve so many systems and so many complex issues. On the other hand, its very comprehensiveness even if limited to--for example--land-based air defense systems, would have several advantages. First, as already mentioned, it would promise much greater gains than individual agreements on relatively minor systems. The program would involve major systems--weapons like Patriot, I-Hawk and Roland that are central to Alliance capabilities, rather than relatively minor tactical weapons. Second, it would require consistent agreement on fundamental issues that have been tackled separately or left out entirely. Third, it would be easier to demonstrate that not only can the Alliance be made better off, but that each country can be made better off by the agreement than by each country going its own way or by ad hoc agreement among limited numbers of countries. Fourth, a comprehensive agreement would cover more systems, making it

easier for the French, Germans, and British to contribute systems that they have developed.

If it is argued that the French and British will never again buy a major weapon system from the US (the French have never bought any, so "again" is somewhat inappropriate), then this is really an argument that NATO standardization is impossible except through ad hoc development and production agreements involving two or three countries--with the US generally excluded.

A comprehensive agreement will be impossible if the four major producers are unwilling to compromise in a way which makes each better off and at the same time protects the interests of the smaller producers and consumers. The only way to test the premise is to undertake negotiations for such an agreement. In such negotiations, the US would have to offer real concessions but in return would demand similar concessions from the major European weapons producers. It would be expected, given current budgets, that over two-thirds of the weapons would be US developed: the Europeans would have to admit that they are not in a position to produce a full line of weapons, even in combination. On the other hand, the US might have to relinquish control of some licensed systems for foreign sales, while the Europeans would have to engage in cooperation in weapon development and production programs that might infringe on their sovereignty.

No doubt such an agreement would fall short of free trade in arms. Certain jobs and technical industries would be protected. Certain unique non-NATO military missions would be pursued. Thus, the increases in economic efficiency would not reach a theoretical optimum that some might claim is possible.

The family of weapons--as now conceived--contains built-in contradictions that will make attaining meaningful and enforceable agreements unlikely. If that is the case, the more

comprehensive agreement would result in significant gains if it is achieved. If it fails, the Alliance would be no worse off for trying.

REFERENCES: CHAPTER VII

[1] Thomas A. Callaghan, Jr., *US/European Cooperation in Military and Civil Technology*, Revised Edition, Center for Strategic and International Studies, Georgetown University, Washington, DC, September 1975.

[2] Ellen Frost, "NATO RSI: Toward A Common Defense Market," cited and quoted extensively in *Allied Interdependence Newsletter, No. 18*, Center for Strategic and International Studies, 18 January 1980, pp. 9-13.

[3] *The Effects of the Tokyo Round of Multilateral Trade Negotiations on the U.S. Economy: An Updated View*, Congressional Budget Office, July 1979.

[4] *Rationalization/Standardization Within NATO*, A Report to the United States Congress by Harold Brown, Secretary of Defense, Fifth Report, January 1979.

[5] *Rationalization/Standardization Within NATO*, A Report to the United States Congress by Harold Brown, Secretary of Defense, Sixth Report, January 1980.

APPENDIX A

RELATIONSHIP AMONG TABLES AND APPENDICES CONTAINING NATO TACTICAL MISSILE INFORMATION

RELATIONSHIP AMONG TABLES AND APPENDICES CONTAINING NATO TACTICAL MISSILE INFORMATION

I. BACKGROUND INFORMATION

A. Table 12 - Tactical Missile Types, Launch Platform, Target, US Mission Abbreviation, and French Abbreviations.

B. Appendix B - Official US Missile Designations from DoD Directive 4120.15-L.

II. MISSILE PROGRAMS (Derived from [2-14] of Chapter IV)

A. Table 13 - Development programs by country and by time period (1939-1945, then by 10 year intervals). Includes some nuclear programs and only most significant variations of tactical missile family.

B. Table 17 - List of programs by strategic purpose and country. Includes most extensive number of program variations, i.e., more than in Table 13 or Appendix C or D.

Tables 15 and 16 - Number of programs by strategic purpose for each country derived from Table 17.

C. Appendix D - List of missiles by country, IOC, and characteristics. Missiles are divided into six major types, each of which has two or three subtypes making a total of sixteen subtypes. The missiles are in two groups: the minimum program and the redundant program so that the reader can easily scan the makeup of the minimum.

Table D-1 - Minimum Program

Table D-2 - Redundant Program

D. Appendix C - Programs in Appendix D listed by five year period with type, developing country, and name. The French R.422 surface-to-air missile was inadvertently omitted from Appendix D but is included in Appendix C as well as Tables 13 and 17.

Table 11 - Number of European programs, total and cooperative: before 1969, and 1969 and after. This table is derived from Appendix C.

Table 18 (also S-6) - Number of new tactical missile programs by mission and five year period for US and Europe. This table is derived from Appendix C.

III. MISSILE COSTS

A. Tables 25 (US), 26 (France), 27 (UK), 28 (FRG) - A separate table for each country containing development cost and source of cost estimate used for each program listed in Appendix D with the exception of Sea Wolf which was inadvertantly omitted. Programs are grouped by missile type within each table. Cost totals by subtype, type and all types together are shown in each table, i.e., for each country.

B. Table 19 - Tactical missile development spending by missile type and subtypes and country. This is a summary of Tables 25-28.

C. Table 30 - Minimum and redundant programs and cost by missile type. This table lists programs as divided in Appendix D into minimum and redundant programs, using costs in Tables 25-28.

D. Table 29 - Minimum and redundant missile programs. Summary of costs in Table 30 by six major missile types.

E. Table 31 (also S-8) - Estimated redundant spending costs for completed projected projects by missile type from Table 29.

F. Table 33 - Minimum and redundant tactical missile spending by five year periods. This table is derived using typical R&D spending curves from Reference [2] of Chapter VI, costs from Tables 25-28 and IOCs from Appendix D. Cost totals are consistent with Tables 19, 29, 30, and 31.

IV. CONTRACTORS

A. Appendix E - Prime contractors and their tactical missile programs. Programs include current operational weapons.

B. Table 23 - Numbers of contractors that worked on each missile type in each country, derived from Appendix E.

APPENDIX B

US MISSILE DESIGNATIONS

Table B-1. MISSILE DESIGNATIONS

Designations			
Operational Status	**Launch Environment**	**Basic Mission**	**Vehicle Type**
J Special Test, Temporary	A Air	D Decoy	M Guided Missile/Drcne
N Special Test, Permanent	B Multiple	E Special Electronics Installation	N Probe
X Experimental	C Coffin	G Surface Attack	R Rocket
Y Prototype	F Individual	I Intercept Aerial	
Z Planning	G Runway	Q Drone	
	H Silo Stored	T Training	
	L Silo Launched	U Underwater Attack	
	M Mobile	W Weather	
	P Soft Pad		
	R Ship		
	S Underwater		

Sample

Y A I M - 7 F

Status Prefix Symbol (Prototype) — Y

Launch Environment Symbol (Air Launched) — A

Mission Symbol (Intercept) — I

Vehicle Type Symbol (Guided Missile) — M

Design Number (7th Missile) — 7

Series Symbol (6th Version of AIM-7) — F

Source: DoD Directive 4120.15-L, Department of Defense, October 1977, p. 2-2, Figures 2-1 and 2-2.

APPENDIX C

NEW TACTICAL MISSILES BY TYPE, DEVELOPER, AND NAME

Table C-1. NEW TACTICAL MISSILES BY TYPE, DEVELOPER, AND NAME

Period	Type	Weapon	Developer
1949-53	Surface-to-air (land)	Nike Ajax (MIM-3)	US
	Surface-to-air (sea)	Terrier (RIM-2)	US
1954-58	Surface-to-air (land)	Hawk (MIM-23)	US
		Bomarc (CIM-10A)	US
		Nike Hercules (MIM-14A)	US
		Bloodhound I	UK
		Parca	France
		R.422	France
	Surface-to-air (sea)	Tartar (RIM-24)	US
		Talos (RIM-8)	US
	Air-to-air	Falcon (AIM-4A)	US
		Sidewinder (AIM-9B)	US
		Sparrow (AIM-7A)	US
		AA.20	France
		R.511	France
		Firestreak	UK
	Anti-tank	SS.10	France
		Entac	France
		SS.11	France
1959-63	Surface-to-air (land)	Thunderbird I	UK
	Surface-to-air (sea)	Masurca	France
		Seaslug	UK
		Seacat	UK
	Air-to-air	R.530	France
	Anti-tank	Cobra/Mamba	FRG
		Vigilant	
	Air-to-surface	Bullpup (AGM-12)	US
		Shrike (AGM-45)	US
		AS.11/12	France
		AS.20	France
		AS.30	France
1964-68	Surface-to-air (land)	Chaparral (MIM-72)	US
		Redeye (FIM-43A)	US
		Rapier	UK
		Blowpipe	UK
		Crotale	France
	Surface-to-air (land)	Sea Sparrow	US
		Standard	US
		Sea Dart	UK
	Air-to-air	Red Top	UK
	Anti-tank	Shillelagh (MGM-51)	US
		Harpon	France
		SS-12	France

Source: Appendix D, Tables D-1 and D-2, except that R.422 was not included in Appendix D.

(Continued)

Table C-1. (Concluded)

Period	Type	Weapon	Developer
1964-68	Air-to-surface	Walleye (AGM-62)	US
		Paveway (KMU-343 et seq)	US
		Martel (AS.37)	France[a]
		Martel (AJ.168)	UK[a]
1969-73	Surface-to-air (land)	Improved Hawk (MIM-238)	US
		Tigercat	UK
	Air-to-air	Phoenix (AIM-54)	US
	Anti-tank	Tow (BGM-71)	US
		Dragon (FGM-77)	US
		Milan	France/FRG
		Swingfire	UK
	Air-to-surface	Hobos	US
		Maverick (AGM-65)	US
	Surface-to-surface	Exocet (MM.38)	France
1974-78	Surface-to-air (land)	Roland I	France/FRG
	Surface-to-air (sea)	Sea Wolf	UK
		Standard 2	US
	Air-to-air	Magic (R.550)	France
		Skyflash	UK
	Anti-tank	Hot	France/FRG
	Air-to-surface	Exocet (AM.39)	France
		Kormoran	FRG
		Condor[b]	US
	Surface-to-surface	Harpoon (RGM-84A)	US
		Otomat	France/Italy
1979-	Surface-to-air (land)	Patriot (MIM-104)	US
		US Roland (MIM-115)	US
		Roland II	France/FRG
		Stinger (FIM-92A	US
	Air-to-air	Super 530	France
	Anti-tank	Hellfire (AGM-114A)	US
	Air-to-surface	GBU-15	US
		Harm (AGM-88A)	US
		Sea Skua	UK
	Surface-to-surface	Copperhead (M712)	US

[a]Martel counted as one missile in Table 18 and S-6.

[b]Development completed, but not deployed.

Source: Appendix D, Tables D-1 and D-2.

APPENDIX D

MISSILE CHARACTERISTICS

Table D-1. NATO TACTICAL MISSILES: DESCRIPTIVE CHARACTERISTICS: MINIMUM PROGRAM

Missile Type	Missile Name/US Designation	IOC	Guidance		Maximum		Remarks
			Initial/Mid-Course	Terminal	Weight (kg)	Range (km)	
Surface-to-air (land)							
Man-Portable	Redeye/FIM-43	1968	IR	IR	8.2	3.4	First generation man portable weapon, Sidewinder technology, tail-on only.
	Stinger/FIM-92	1979	IR	IR	10.1	4.8	Second generation man portable weapon. Has IFF wide-aspect capabilities.
Short-to-medium	Chapa· ·al/MIM-72	1966	IR	IR	84.0	17.7	Uses four Sidewinder AIM-9D missiles mounted on self-propelled launcher.
	Tigercat	1969	Optical or TV track, radio command	Same	68	3.5	Adaptation of Seacat to land basing.
	Rapier	1967	Optical or radar track, radio command	Same	65	5	Originally optical only. Blindfire radar in 1975.
	Roland II	1980/ 1981	IR/Radio command	Radar beam riding	63	6.2	France/Germany version of optically tracked Roland I (Euromissile)
High-to-medium	BOMARC/CIM-10	1958	Radio command	Active radar	6,804	370	Supersonic pilotless aircraft, extended range version operational until 1972.
	Nike Ajax/MIM-3	1953	Radio command radar beam riding	Radar beam riding command	550	40	First high altitude SAM to be deployed. Retired in 1968.
	Nike Hercules/MIM-14B	1958	As Ajax	As Ajax	4,720	140	Version still deployed in Europe.
	Hawk/MIM-23A	1954	Semi-active radio homing	Semi-active radar homing	587	35	Low altitude capability, semi-portable.
	Improved Hawk/MIM-23-B	1972	As Hawk	As Hawk	626	40	Improved radars, electronics. Size reduced to true mobile capability.
	Patriot/MIM-114	1981	Radio command	Semi-active homing	Approx. 1,000	Unknown	Multiple-target capability using phased-array radar. Truck-via-missile.

Sources: References [3-14], Chapter IV.

Table D-1. (Continued)

Missile Type	Missile Name/US Designation	IOC	Guidance		Maximum		Remarks
			Initial/Mid-Course	Terminal	Weight (kg)	Range (km)	
Surface-to-air (sea)							
Short range	Seacat	1962	Optical or radar track, radio command	Radio command	68	3.5	Based on Australian Malkara anti-tank missile.
	Seasparrow/RIM-7H	1967	Radio command	Semi-active radar homing	200	25	AIM-7E (AAM) adapted for ship launch. NATO Seasparrow IOC in 1973.
Medium range	Terrier/RIM 2 (Tartar/RIM 24)	1953	Radar beam riding	Semi-active radar	1,315 (646)	19.3 (17.7)	With similar TARTAR provided a series of medium range modifications leading to STANDARD.
	Standard Missile/RIM 66	1966	Semi-active radar	Semi-active radar	581	30.6	Replaces Tartar in installations, Tartar/Terrier in range.
Long range	Talos/RIM 8	1958	Radar beam riding	Semi-active radar	1,590	120	Solid booster, ramjet sustainer engine. Mach 3 + cruise speed.
	Standard 2/RIM 67	1978	Semi-active radar	Semi-active radar	2,350	121	Replaces Terrier in installations. Terrier/Talos in range.
Air-to-air							
Very short range	Magic/R.550	1975	Infrared	Infrared	89.9	10	First "dogfight" missile.
Short range (IR)	Sidewinder family/AIM-9B through AIM-9L	1956/ 1979	Infrared	Infrared	70-85	3-18	The first generation infrared homing missile and its seven major modifications. In use at one time or another by all NATO countries.
Medium range	Sparrow family/AIM-7A through AIM-7M	1956/ 1977	Semi-active radar	Semi-active radar	140-230	8-100	The first air-to-air missile to use semi-active homing. Five major modifications have seen service in NATO.
Long range	Phoenix/AIM-54A	1970	Semi-active radar	Active radar	447	209	Deployed in F-14 aircraft with radar systems that permit six targets to be engaged simultaneously.

Sources: References [3-14], Chapter IV.

Table D-1. (Continued)

Missile Type	Missile Name/US Designation	IOC	Guidance		Maximum		Remarks
			Initial/Mid-Course	Terminal	Weight (kg)	Range (km)	
Anti-tank							
Man-Portable	SS.10	1955	Wire command, visual	n.a.	15	1.6	First post World War II ATM.
	Entac/MGM 32	1958	Wire command visually tracked	n.a.	12	2	More successful of two French-developed first generation AT missiles using wire guidance.
	Milan	1972	Automatic wire command IR tracking	n.a.	6.7	2	Application of technology from SS.12/Harpon to portable weapon, third generation.
Medium-to-heavy	SS.11	1958	Wire command	n.a.	29.9	3	First generation vehicle mounted weapon. Utilized guidance principle from AA20 AAM.
	SS.12	1962	Automatic wire command with IR tracking	n.a.	7/	3	Second generation AT weapon with semi-automatic guidance also AS12 air launched version.
	TOW	1969	Automatic wire command optical tracking	n.a.	20.9	3.75	Second generation AT weapon most widely distributed of any heavy missile. Least demanding of operator skill.
Heliborne	Hellfire	1981	Semi-active laser guidance	n.a.	43	Unknown	Designed to eventually be "fire and forget," with active homing head of some sort.

Sources: References [3-14], Chapter IV.

Table D-1. (Concluded)

Missile Type	Missile Name/US Designation	IOC	Guidance		Maximum		Remarks
			Initial/Mid-Course	Terminal	Weight (kg)	Range (km)	
Air-to-surface							
Anti-radiation	Shrike/AGM-45	1963	Passive radiation seeker	Radiation homing all the way	177	40	First effective anti-radiation missile. Many modifications and improvements to seeker.
	Harm/AGM-88	1980	Passive radiation seeker	Can lock-on after launch	367	18.5	Higher speed and wider range of capabilities than Shrike.
Other	Bullpup/AGM-12B	1959	Radio command	Radio command	259	11.3	Pilot had to hold sight on target and fly missile to line-of-sight.
	Walleye/AGM-62	1966	Radio command	TV camera; image lock on	499	25.7	Television guided glide bomb.
	Maverick/AGM-65A	1972	Automatic TV	Automatic TV	209.5	22.5	Television guided weapon. Three major modifications including imaging infrared under development.
	Paveway	1968/ 1979	Free-fall	Semi-active laser	Various	n.a.	Guided bomb guidance kits to attach to standard free-fall bombs.
	GBU-15	1981	Multi-mode	Multi-mode	Various Rqts.	Unknown	Development of Hobos, ultimately winged glide bombs.
	Kormoran	1977	Inertial	Active radar	600	37	Anti-ship missile with launch and leave capability. A/C search radar provides cruise data to missile prior to launch.
Surface-to-surface							
Land	Copperhead M-712	1980	Gun-launched ballistic	Semi-active laser	63.5	20	155 mm projectile is guided to target illuminated by ground base laser in view of impact zone.
Anti-ship	Exocet MM.38	1972	Inertial	Active radar	735	45	Exists now in four other versions. Two air-launched and two surface-launched with increased range.

Sources: References [3-14], Chapter IV.

Table D-2. NATO TACTICAL MISSILES: DESCRIPTIVE CHARACTERISTICS: REDUNDANT PROGRAM

Missile Type	Missile Name/US Designation	IOC	Guidance		Maximum		Remarks
			Initial/Mid-Course	Terminal	Weight (kg)	Range (km)	
Surface-to-air (land)							
Man-Portable	Blowpipe	1968	Optical track, radio command	Same	12.7	3	Also fitted on subs and small patrol vessels as point defense.
Short-to-medium	Crotale	1968	Radar track, radio command	Radio command IR proximity fuse	80	8.5	Work begun on South African initiative.
	Roland I	1977	Optical track, radio command with IR tracking	Proximity fuse	63	6.2	Developed jointly by France and Germany.
	US Roland	196[illegible]	Radar beam rider after IR capture	Proximity fuse	63	6.2	US version of Roland II.
High-to-medium	Bloodhound MK1/2	1958/1964	Radar track, radio command	SARH	2,300	80^+	Only British HIMAD sold overseas in large quantity.
	Thunderbird MK1/2	1960/1965	Radar track, radio command	SARH	Unknown	75^+	Replaced in UK service by Hawk.
	Parca	1958	Radar track, radio command	Radio command	1,100	32	Only briefly operational. Preceded by Matra R.422.

Sources: References [3-14], Chapter IV.

Table D-2. (Continued)

Missile Type	Missile Name/US Designation	Guidance			Maximum		Remarks
		IOC	Initial/Mid-Course	Terminal	Weight (kg)	Range (km)	
Surface-to-air (sea)							
Short range	Seawolf[a]	1978	Radio command, radar track	Command	63	6	Uses Rapier-type guidance. Anti-missile capability claimed.
Medium range	Masurca	1960	Radio command, radar track	SARH	2,080	50	Originally command guided all the way. Now in service on two French cruisers only.
	Seaslug 1/2	1961/ ?	Radar beam rider	Radar beam	Unknown	45/58	On county-class UK, destroyers.
Long range	Sea Dart 1/2	1967/ ?	Semi-active radar homing all the way	SARH	1,210	80+	Ram-jet sustainer engine. (Sea Dart 2 to be in service through year 2000).
Air-to-air							
Short range	Falcon family	1956/ 1963	Semi-active radar, IR	SARH, IR	50/119	8/11	Nine basic versions, (5 SARH, 4 IR) including 2 under Swedish licenses. USAF aircraft only in U[illegible]
	AA.20	1956	Visual track, radio command	Radio command	134	4	First European AAM.
	R.5[illegible]	1958	Semi-active radar	Semi-active radar	184	7	Had height limitation requiring minimum of 10,000 feet of altitude.
	Firestreak	1958	IR homing	IR homing	136	8	Production ended in 1969. Superseded by Red Top.
	Red Top	1964	IR homing	IR homing	150	11	Speed and accuracy improvements over Firestreak.
Medium range	R.530	1963	IR or SARH	IR or SARH	195	18	Missile may be manufactured with either SARH or IR head.
	Super 530	1978	SARH	SARH	200	35	Weapon for Mirage F-1 and Mirage 2000.
	Skyflash	1977	SARH	SARH	193	50	Improvement on US Sparrow design.

[a]Inadvertantly omitted in estimates of Table 27. Would add $30 million to UK program.

Sources: References [3-14], Chapter IV.

Table D-2. (Continued)

Missile Type	Missile Name/US Designation	IOC	Guidance		Maximum		Remarks
			Initial/Mid-Course	Terminal	Weight (kg)	Range (km)	
Anti-tank							
Man-Portable	Dragon/FGM-77A(M-47)	1972	Wire command	n.a.	12	1	First US man-portable *guided* AT weapon.
	Vigilant	1963	Wire command	n.a.	14	1.6	First missile to have velocity control.
	Cobra/Mamba	1960/ 1972	Wire command	n.a.	10	2	Originally a Swiss design, later developed by MBB in Germany.
Medium-to-heavy	Shillelagh/MGM-51A	1967	Automatic radio command, IR truck	n.a.	27	5.2	Cannon launched from 152mm tank gun.
	Swingfire	1969	Wire command	n.a.	27	4.0	Can be turned through large angles after launch (up to 45°).
	Hot	1977	Automatic wire command, IR track	n.a.	25	4.0	Euromissile (French/FRG) system. Also has heliborne mode.
Heliborne	Harpon	1967	Automatic wire command	n.a.	30	3	AS.11 adopted from SS.11 available as heliborne AT missile.
Air-to-surface							
Anti-radiation	Martel AS.37	1968	Autopilot cruise	Passive radiation searcher	530	60	Joint design UK/French. UK (AJ168) does not use anti-radar version.

Sources: References [3-14], Chapter IV.

Table D-2. (Concluded)

Missile Type	Missile Name/US Designation	IOC	Guidance		Maximum		Remarks
			Initial/Mid-Course	Terminal	Weight (kg)	Range (km)	
Air-to-surface							
Other	Martel AJ168	1968	Autopilot curise	TV-radio command	550	60	TV guided version of AS.37 joint UK/French design.
	AS.1/AS.12	1960	Wire command via variable thrusters	n.a.	77	8	Air-launched version of SS.11 and SS.12. AS.11 is heliborne ATM.
	AS.20	1961	Radio command, visual track	Radio command	143	7	Air-to-surface adaptation of AA.20.
	AS.30	1960/ 1964	Radio command, optical track/automatic radio command	Radio command	520	11	Directional control via thrusters as in AS.12. AS.30L, laser guided weapon to be added to inventcry in 1980s.
	Exocet AM38/AM39	1974/ 1977	Inertial	Active radar	650	38+/75	Air-to-surface version of MM38 surface-to-surface missile. AM39 has double AM38 range.
	Sea Skua	1980	Autopilot, sea skimmer	SARH	147	14.5	For helicopter launch, anti-ship warhead.
	Condor	1976	Radio command	SARH	970	180	Anti-shipping weapon. Cancelled at end of development.
	Hobos	1969	Electro-optical	Electro-optical	n.a.	n.a.	Kits for guidance attaching to standard free-fall bombs. Subsequent IR, laser guidance kits.
Surface-to-surface							
Anti-ship	Harpoon RGM-84A	1976	Inertial, sea skimmer	Active radar	635	110	In NATO use (as is Exocet). Also available in air launched and submarine launched versions.
	Otomat	1978	Autopilot, command	Active radar	770	100+	Air-launched version is in development.

Sources: References [3-14], Chapter IV.

APPENDIX E

PRIME CONTRACTORS AND THEIR TACTICAL MISSILE SYSTEMS: FOUR MAJOR NATO POWERS

Table E-1. PRIME CONTRACTORS AND THEIR TACTICAL MISSILE SYSTEMS: FOUR MAJOR NATO POWERS

Company	Weapons
US	
Boeing Aerospace	AGM-86, US Roland
Ford Aerospace	AIM-9L, Chaparral, Stinger
General Dynamics	Tomahawk, AIM-7F, Standard I & II, Stinger
Hughes Aircraft	Maverick, Phoenix, US Roland, Tow
LTV	Lance
McDonnell Douglas	Harpoon, Dragon[a], Rapier[b]
Martin Marietta	AIM-9L, Copperhead
Raytheon	Dragon[a], Improved Hawk, Patriot, AIM-7F, Sea Sparrow
Rockwell	Hellfire, GBU-15
Texas Instruments	Harm, Shrike
Western Electric	NIKE Hercules[c]
France	
Aerospatiale	Roland I, AS.20, AS.30, Harpon, SS.12, Hot, Milan, Exocet
Matra	Crotale, R.530, Super 530, R.550, Martel, Otomat
Ruelle Arsenal	Masurca
FRG	
Messerschmitt-Bolkow-Böhm	Roland II, Hot, Milan, Kormoran
Bodenseewerk Geratetechnik	AIM-9L (licensee)
UK	
British Aerospace	Bloodhound, Rapier, Thunderbird, Sea Dart, Seaslug, Sea Wolf, Red Top, Skyflash, Sea Skua, Swingfire, Vigilant
Short Brothers and Harland	Blowpipe, Seacat

[a] Raytheon is the sole producer although McDonnell Douglas is the prime contractor.

[b] UK missile which may be licensed for US production.

[c] No longer in production but this missile is the predecessor of the ABM system which became Safeguard. Western Electric should still be considered a viable prime contractor for tactical missiles.

Sources: References [3-14] of Chapter IV.

APPENDIX F

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